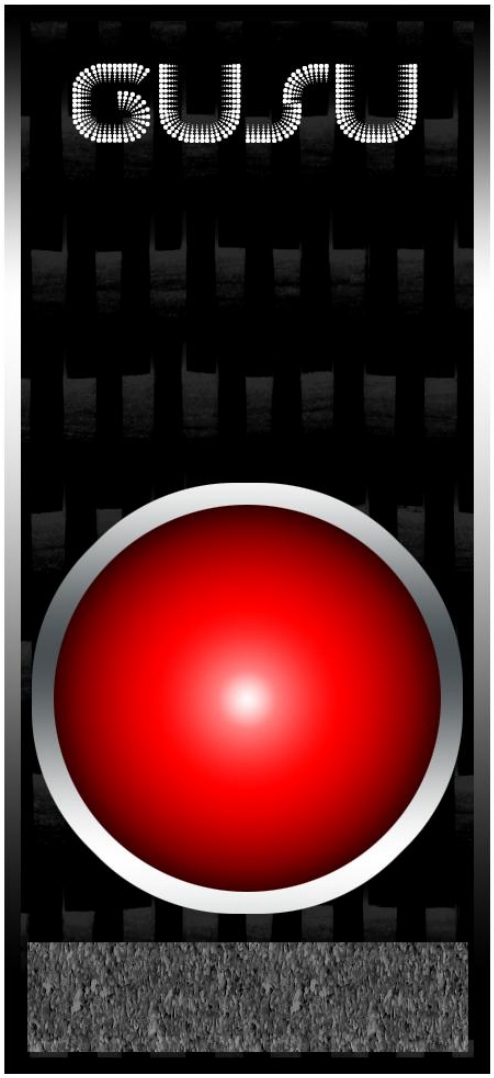

Get Up Stand Up

It knows when you're sleeping It knows when you're awake

EEL4915 | August 6, 2009 | Group 5

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1.0 Executive Summary

There is always a need for alarm clocks in our daily society. They are used for many reasons. The most common and popular uses are to be woken up in the morning for school or work. Although these would seem the obvious reasons there are others such as reminding the user about a certain event in their day or even to let them know when a deadline needs to be completed. Whatever the reason is, there is always a demand for these ingenious and effective electronic devices.

With the growing technical revolution taking place, electronic companies are continually researching new ways to improve upon the design of current alarm clocks. Some of these new modifications include an improved visual screen, better sound quality, and more features that can be used in the common person's lifestyle. More and more companies are using LCD screen displays as an aesthetic way to illustrate the software and features that these new alarm clocks have.

While most alarm clocks contain an AM/FM tuner, some corporations are looking into satellite radio to incorporate into their designs. Using this technology would bring in a much broader audience than the regular AM/FM users because the general public would be exposed to other stations than just AM/FM. Sound quality is something people are always looking to improve upon and developing new types of sound speakers are high on the list of improvements made to the daily alarm clocks. New software is always being developed to improve the sound quality of the actual music files that can be played on the newer alarm clocks such as MP3, FLAC, and OGG. To use this improved software and file formats new alarm clocks must have software developed to meet these requirements.

One other feature that has been gaining remarkable popularity recently has been the addition of an Ethernet jack or wireless capability so the user can connect their alarm clock into their home network. The major advantages of this would be so that the home user can awake to the local news, get weather reports from their area, and even to check the regional traffic reports so that they can adjust their commute to work or school accordingly. This new technology has been gaining momentum with the developing companies as to provide software and firmware upgrades to their alarm clocks to keep their systems up to date. New updates have been made available to these alarm clocks such as new user interfaces and downloadable content.

The "Go Go" American lifestyle has changed throughout recent decades with more and more people working longer hours. In consequence to this, more people are losing sleep due to the constant stress of work, school, and children. But in order to keep their current lifestyles these demands must be met. Figure

1.0.1 shows a day in the life of a typical American employee as researched by the National Sleep Foundation.

Figure 1.0.1: Shows the day in the life of a typical American Worker. Reprinted with permission from the National Sleep Foundation.

According to the National Sleep Foundation the average time spent sleeping every night is between six and seven hours, while the National Sleep Foundation recommends that people get between seven and nine hours of sleep to function at their peak performance. Some other staggering statistics that were found is that about 25% of American workers tend to take a quick nap while at the workplace and more than half of the American workforce brings home some of their work to complete [1]. These figures show how not getting enough sleep at home can hinder employment productivity and performance.

Now, bear in mind that most alarm clocks cannot solve this dilemma but they do prove to be useful in dealing with this daily occurrence. Modern alarm clocks allow people to prioritize their time more efficiently. In today's progressive society time is of the essence and in the business world time is money. With today's alarm clocks they help give people's lives a more structured schedule, this can help them in having a better routine which in turn can help them get a better night's rest. Current alarm clocks have lost their effectiveness in dealing with these sleep problems. The GuSu prototype will attempt to solve these issues with a better design that will help people with their dynamic lifestyles.

1.1 Problem Statement

Waking up, especially for some college students, can be troublesome. In a worst case scenario an individual may have a half dozen alarms scattered throughout a room set for one or many times, perhaps even with a few outside their room, and still find themselves shutting all of these alarms off and getting back in bed, only to wake up later realizing they are late to start the day. Most solutions proposed and even commercially available have the alarm clock "launch" an object that must be retrieved, or task the individual with solving some form of problem or puzzle to quiet the alarm. However this does not defeat the individual who is able to leave their room to shut off an alarm and still get back in bed, because in essence this still leaves the person with a snooze or turn off method for the alarm, and perhaps after a few weeks will become very adept at whatever task

must be performed to silence the alarm, and now have not only spent time dealing with the alarm, but also gone back to bed, thus resulting in even more delay to their morning routine.

An alarm clock serves three purposes; waking the user when they wish to be awoken, getting the user out of bed, and waking them in a "non-harmful" or disorientating way. These three requirements can be further broken down in the following way. The alarm clock obviously must be able to keep track of time, and let the user decide what time they want to wake up. Waking up the user alone is not enough, the ideal alarm clock ensures that the user also gets up and out of bed in a timely fashion and stays out of bed (by having no snooze or off button), in essence preventing both oversleeping and snoozing. Finally, users have different needs and preferences for being roused from slumber. For example, some individuals require sudden, often loud or jolting methods, while others wake better to a slow process, such as subtle music or talk radio followed by lights coming on, scents of coffee, or an old fashioned alarm tone signifying the time to get up has passed.

1.2 Solution

Building a clock from the ground up that has no snooze or off button and removing any direct action on part of the user that can silence the alarm is the first step in satisfying the three aforementioned design necessities of a better alarm clock system. But the alarm must turn off somehow, so the clock will include sensors that tell it whether someone is in the bed or not, and will run off of the simple logic that if it is time to get up, and someone is in the bed, it will follow it's programmed routine. This motivates the user by giving them no option but to get out of bed and stay out of bed. In addition, a battery backup system serves two purposes; it helps keep the internal clock correct, and ensures the user cannot silence the alarm by unplugging its power source. The internal clock itself may be either an atomic clock, set for time-zone by the user, or a binary clock adjusted by the user.

For meeting a user's "waking preferences" the clock shall have the following abilities that tie in to the alarm clocks wireless modules and alarm speaker. An FM tuner, an SD card slot for mp3 storage and mp3 decoder chip, a built in common tone alarm, Zigbee interfaces with lights and coffee makers, seven day programmability, and timing/ordering adjustments for what alarm option will occur (for example if the user would like the FM radio to play through the speaker fifteen minutes before the wake up time, at which point lights may turn on and the alarm tone will sound).

To further prevent the user "tricking" the clock into silencing, the alarm settings can only be changed and tested when a turnkey slot on the bottom of the unit is turned from the Running mode to a Test/Set mode. This turnkey will be ignored during the alarm period.

1.3 Research Methodology

The purpose of research methods is to successfully explore information that is relevant to the design that will be put into practice. There are various methods of research that are used all the time throughout the academic and professional disciplines. Some of these methods include use of a library, the internet, and even life experiences. The purpose of doing research before designing a project is to measure the idea's originality and creativity. There are other factors that were taken into account which included the significance, contribution, and technical soundness of the design at hand. Looking at research from another point of view there are two main aspects that define research; those are qualitative versus quantitative. When comparing both of these measures of research the qualitative side can be defined as the measure of the quality of the project. This means that the qualitative measures will be found in the research and analysis of the data and physical attributes of the design. On the other side there is the quantitative approach which includes the research of and analysis of the numerical data. This side focuses more on the numbers and equations that will hold the design together.

The main method that was used in designing the GuSu project was the internet which provided an endless amount of information at the team's disposal. The GuSu project team did countless research and searched the internet for ideas that suited the team members' needs. After we brainstormed and looked at projects from past UCF Senior Design groups, the team decided on the GuSu prototype that is explained in detail in this document. Other projects that were comparable to the GuSu project can be found in section 4.4 of this document. Once the idea was agreed upon research that used the internet began. This investigation commenced while we searched for parts and devices that would fit the brainstormed ideas. The team first searched for each module that was used in the prototype and compare them to other products of similar likeness. This method was done for each of the modules that were used in the GuSu design. After completing this research the most favorable parts were chosen to be used in its design. Once these parts had been obtained they were put into the design and implementation phase of the project which will be discussed in sections 1.4 and 1.5 of the document.

1.4 Design Methodology

This section describes the techniques of how the GuSu prototype was designed. When designing a prototype there are a few dynamics that need to be addressed before the actual design begins. Some of these include the engineering behind the design, the marketing which will provide the product to the public and of course the actual production of the design. First off the research behind the design must be completed first which was discussed in section 1.4. After doing so, the plan can be thought about much more. One thing to point out is how the design's ability can conform to professional standards. A number of points that can be taken into consideration are those of the safety of the design, the

environmental friendliness, and how the designs specifications coincide with any governmental laws or stipulations. Once these different regulations are taken into account the design's architecture can be thought about.

The GuSu design included various modules that are described throughout this technical document. These devices were ordered off the internet and put into practice during the implementation phase of the design. After we received the parts, the project team studied the various schematics and connections that were later made. The central part of the design included a PCB (Printed Circuit Board) that allowed all of these modules to link together. The project team understood the schematics of the devices and had to create circuitry to allow these devices to talk to one another.

Team members Josh and Andrew attended a class given at UCF that taught students to learn how to use the milling machine that created these printed circuit boards. After we had a better understanding of how this machine creates these circuit boards the team was able to better recognize how to design the main board. Following the various schematics behind the devices also allowed the project team to integrate these into the printed circuit board. Once the devices successfully communicated with one another, the software design was thought about. After much research and thought about the design of the GuSu prototype another methodology was put into practice, this is the implementation phase of the project which is discussed in the following section.

1.5 Implementation Methodology

This section describes the implementation phase of the design. The implementation included the actual building and testing of the prototype. The purpose of going about the implementation step of designing was ultimately the deciding factor in which the design had succeeded or failed. As seen in the two previous sections the research was completed as well as the design brainstorming and production.

After these steps were completed the GuSu project team then applied this background information into a real working prototype. The first step in achieving this methodology had been to assemble the purchased devices in a safe and secure environment. The purpose of building this in a safe environment ensured the devices stayed intact and also the builders. Various methods were used when constructing the devices; such as soldering, wiring, and testing. When we soldered and wired up each device to one another as well as the printed circuit board, the project team was careful not to damage the circuitry on the devices. Simple scratching or high heat can ruin an electrical circuit in an instant.

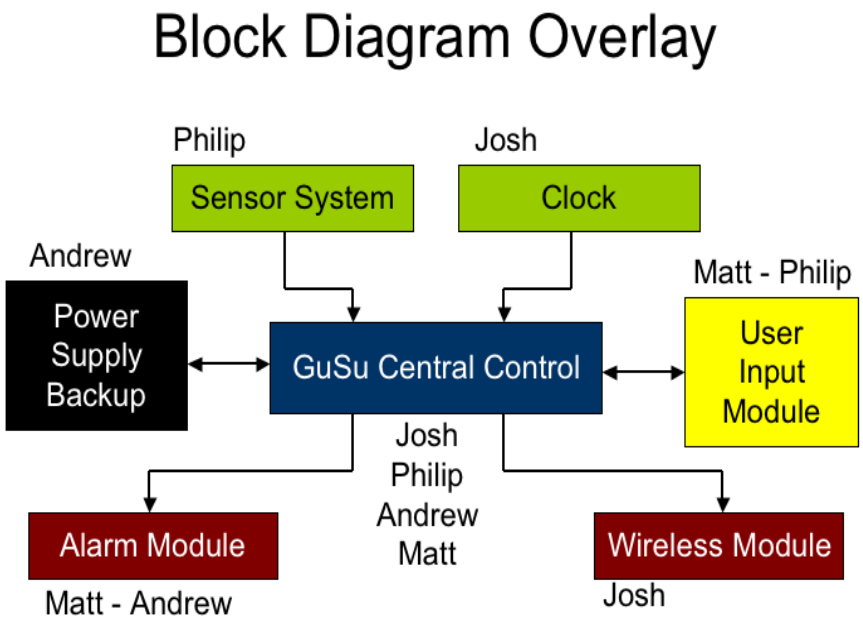

Figure 1.5.1: Overall block diagram of the alarm clock.

Once the devices were connected to one another the testing phase of the implementation methodology came into place. This phase included all the directives needed to make sure the hardware was working properly. The project team had used multi-meters, oscilloscopes, and other electrical testing equipment to ensure there were no bad connections. As soon as this stage had been completed and there were no technical errors the software design had begun. Software design incorporated many different aspects to controlling all of the devices to perform to the team's specifications. This stage of implementation incorporated a lot of hard work and time to make sure the GuSu design carried out the actions described in the document.

1.6 Project Management

This section describes the aspects behind what project management meant and what it did for the designing team. The purpose of project management was a way to plan, organize, and manage resources at the team's disposal to accomplish the goal that was set for the GuSu project team. The main goal of the GuSu project team was to successfully implement the design of GuSu and present it to the fellow Senior Design peers and the UCF faculty. The success of the design decided whether or not the project team was able to achieve the various principles that were instilled in the group members throughout their college career. Some of these principles that were taught throughout the college program were that of working with others and the ability to apply engineering practices and ethics. Since the design met the specified requirements the GuSu

project members knew they had accomplished something meaningful and worthwhile.

To achieve this project management was put into effect. Using project management ensured that the team had been on schedule and allowed the team to make sure deadlines were met. The GuSu project team had set up an active live web folder using Windows Live Mesh which allowed the members to add and update documents, images, and information. This also allowed each team member to view each other's work and use constructive criticism to make sure each member was on the right track. Google Documents were also used when updating documents. The GuSu project team was then using the Google Docs to update information about billing and specifications. Using these methods proved to be a way to achieve the organization and management elements of project management. To achieve the planning aspect of project management a milestone chart was set up at the beginning of the design. A milestone chart is a way of depicting key events along a period of time. Most of these events were deadlines that the GuSu project team had met in order to successfully implement this design. Figure 1.6.1 shows the GuSu milestone chart. Taking into account all of these factors was key to implement project management in a plan this complex, otherwise it was extremely difficult to meet all of the goals that were set beforehand.

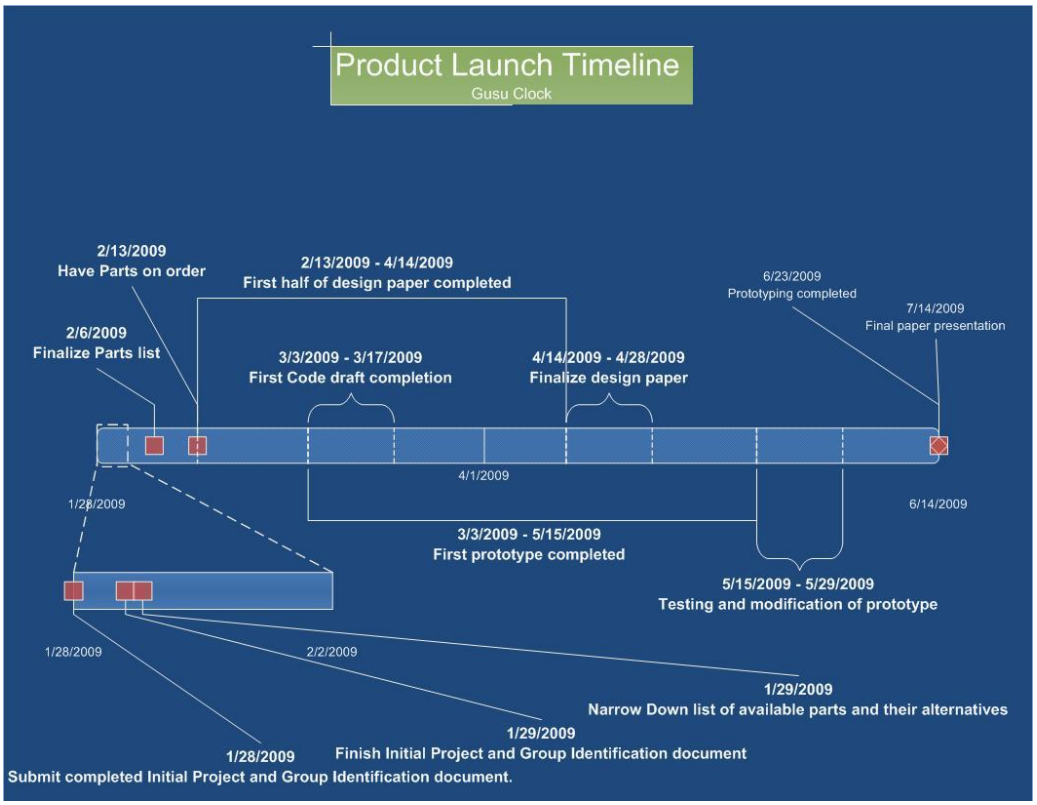

Figure 1.6.1: Milestone chart showing project schedule and deadlines.

Back in the beginning of January 2009 when the Senior Design I semester started the students were told to break into groups of three or four. All four of the group members have previously been in classes with one another and knew that this team would work well together. Every Tuesday and Thursday after the morning class the GuSu team would meet with one another to discuss project ideas and research methods. After deciding on the GuSu design the team continued to meet each week, further discussing components that would be used and how the overall design would function.

The team decided that to break up the 120 page technical design document had been the best way to tackle this challenge. The document write up was evenly divided among the four group members and we each choose a module to research and design. Seen in the following list is a sample of what each member has worked on.

- Andrew: All sections related to Audio output, FM Tuner, Power and Battery backup, Printed Circuit Boards.
- Josh: All sections related to Alarm Clock External Casing, ZigBee, Appliance Module, Microcontroller, and Clock Module.
- Matt: All sections related to LCD display, MP3 decoding, USB reader, Budgets, Executive and Final Design Summaries.
- Philip: All sections related to sensors, User Interface, MP3 decoding, Software design.

After it was decided which team member would tackle each section, all of the members worked on the design document on their spare time at home and school with meetings having continuity from week to week. The team set deadlines for how many pages would be completed with the average completion time being 5 pages per week. Keeping with this schedule the team eventually found that they were ahead of the agenda and had time to spare at the end of the semester to deal with formatting, appendices, and company emails. The team met a few times before the deadline to work on formatting and also proof read the design document. Lastly, the finished documentation needed to be printed and bound, which was later done at Kinko's.

1.7 Similar Projects

There were a few similar projects that were found on the web and in past UCF Senior Design classes that corresponded to the project this design had implemented. The team examined all of these projects to get an idea of how to execute the GuSu system and made it more efficient.

The first project looked into was Lazy@Home [2] designed by a former UCF Senior Design engineering group. The purpose of this project was a hands free approach to controlling different aspects of electrical devices within your home. This group created a base station similar to the GuSu base station that would

control features of the home such as the air conditioning/heating thermostat, the lighting, vents, and even the wall outlets. The main idea behind this project was that it allowed the user of the home to control all of these utilities in their home via web interface so if you left on a vacation you could still control all of your electrical appliances from the internet. The idea behind this was if the user forgot to turn off certain lights after you had left the user could easily turn them on or off from a remote location. Another idea behind this was that when the user was planning their return home they could easily adjust the thermostat so the home would be perfectly cooled or heated to their liking. One more interesting feature that was implemented into the Lazy@Home station was turning on and off lighting outside of the house. The GuSu project team was very intrigued because it allowed their users to turn on outside lights at night so it could seem like someone was at home even though no one was there. Seen in figure 1.7.1 are two diagrams taken from Lazy@Home. The image on the left shows the Use Case diagram of the system and its respective feature components. The image on the right shows the web interface that this team created to control the Lazy@Home base station via the internet.

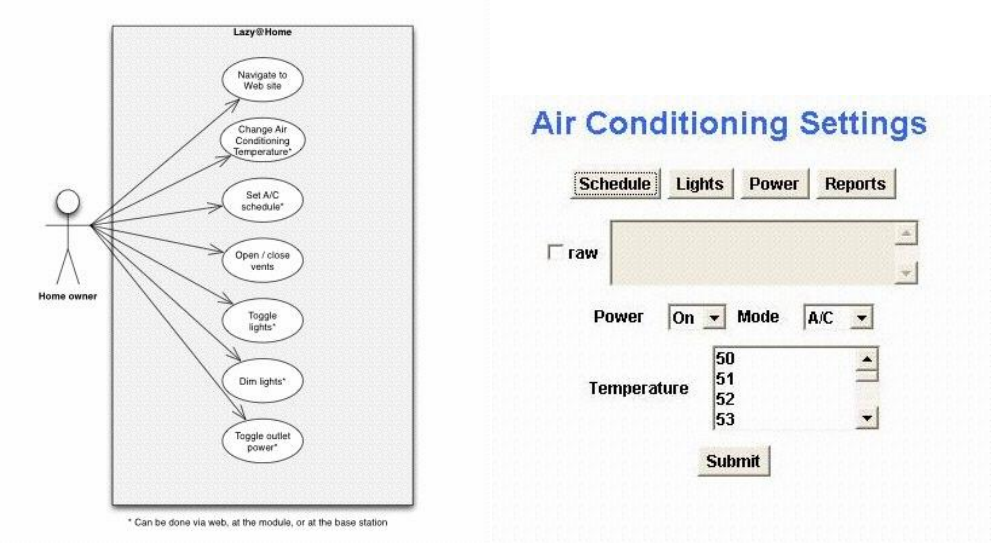

Figure 1.7.1: UML diagram and web interface of the Lazy@Home Senior Design project. Reprinted pending permission from the Lazy@Home UCF Senior Design group.

Other projects which were looked at were similar. One was from a UCF senior design and another from Columbia University. The name of the project at Columbia University was the OH800 [3], an alarm clock that consisted of a base and a ball that would shoot out when the alarm was activated. This project included a solenoid that would push the ball off of the base of the alarm clock and onto the floor which would disconnect the two magnetic switches. This would launch a DC motor to turn on inside of the plastic ball and also activate a sound alarm on the base station. An anti-symmetric disk would rotate within the ball to move it around the floor. In order to deactivate the alarm the person sleeping would have to get out of bed and pick up the ball then return it to the base station

which would reconnect the magnetic switches and thus turning off the alarm. While the ball would sit on the alarm clock base station the battery that would run the DC motor inside the ball could charge via the AC wall outlet. This was similar to the GuSu design in that it required the user's action to do something to deactivate the alarm.

The last project that was looked into that was especially similar to the GuSu design was the PerfectSleepSystem [4] which was also designed by a group in the UCF engineering program. The purpose of this system was to utilize electronic sensors attached to a person's body to optimize their sleep occasions. The PerfectSleepSystem contained sensors that would monitor the heart rate, temperature of the body, and also their movement. The goal of this system was to use those features to calculate which settings were most favorable for a good night's sleep. The PerfectSleepSystem was similar to Lazy@Home in that it would control external electronic devices to allow the user to sleep more sound. Examples of this would be turning off appliances such as the TV or lights. One feature of the PerfectSleepSystem that was found most interesting was the ability to detect the amount of light in the room. Having this feature would allow the base station to turn on its alarm clock to wake the person up at a certain time; whether it is in the morning, afternoon, or at night. The PerfectSleepSystem was fascinating as it could detect when to wake the user up when they entered the light sleep mode based on their movements and heartbeats. An example of the base station is shown in the left image of figure 1.7.2 and examples of where the sensors were placed are shown in the right image.

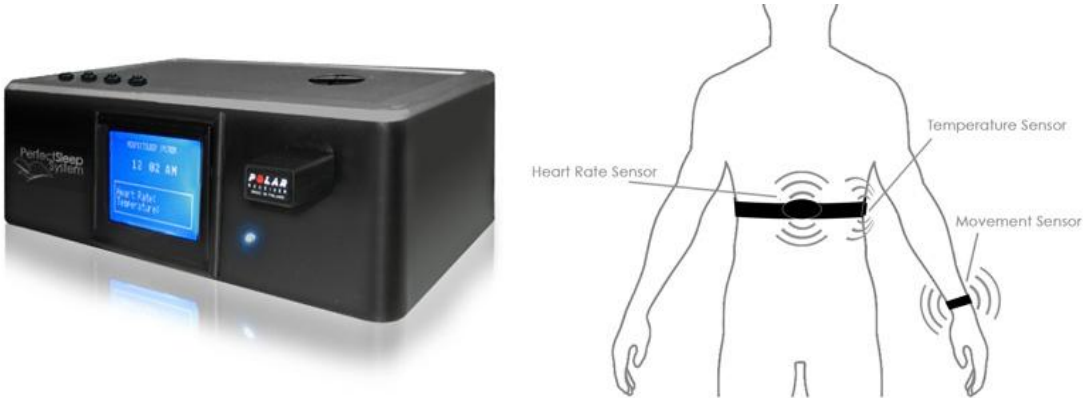

Figure 1.7.2: Base station of the PerfectSleepSystem and a diagram of the sensors involved. Reprinted pending permission from the PerfectSleepSystem UCF Senior Design group.

After we reviewed both of these projects and many others it was found there were similarities in their design compared to the GuSu design. The Lazy@Home system would use the Zigbee protocol as did the GuSu design and all of these systems had utilized the concept of wireless technology to achieve a common goal. Another resemblance between these systems was the base station. These designs used the concept of a base station as the central control unit including the design of GuSu. The purpose of this base station had allowed all features of

the designs to be easily integrated together. The main difference that was seen from these designs compared to the GuSu design was the fundamental function of what each system performed, each system had a different goal to accomplish. Once these designs were looked into, the GuSu project team got a better feel for how this design would be implemented and put into effect.

2.0 Case Design

The alarm clock needs to be enclosed in an aesthetically pleasing and durable case. It will have a single SD card slot and removable back panel for access to the battery compartment. The three options investigated are an ABS plastic box, Plexiglas (Lucite) sheets, or a wood case.

2.1 ABS Plastic Enclosures

ABS plastic boxes are readily available from online retailers and local home hobby stores such as radio shack. They are sturdy, water resistant, and durable. They are also non conductive. The cases are available in clear to opaque colored boxes and available in a variety of sizes (figure 2.1.1).

Figure 2.1.1: Sample ABS enclosures from Polycase Inc.
Reprinted pending permission from Polycase Inc.

Pre built boxes are designed with holes for switches and buttons while providing thin walls allowing easier mounting of said buttons and switches. This is also a drawback for ABS boxes. The enclosure size of the box is also static and the PCB layout has not been finalized at this point. The design calls for a device size of 12x4 but this could change based on further PCB designs and additions to system specifications. The design calls for buttons to be mounted in a circular

fashion which in our research is not available. Many online retailers offer custom ABS enclosures but the costs are prohibitively expensive.

2.2 Lucite Sheets

With Plexiglas sheets, the box can be constructed to our specifications. It can be modified easily and adjusted to the final design of the system. A solvent or adhesive is applied to a finely sanded edge and the solvent is allowed to cure for 12 hours. The edges are then sanded to make a smooth edge. Another option is using an extruded acrylic adhesive like Weld-on #5. It is applied as glue and the seams are taped allowing it to dry for 12 hours. While simple to implement, the aesthetics are certainly compromised with this type of implementation. The available Lucite products are clear and the user would be able to see the internals of the system. While some would prefer the look of the clear case, the group feels this would limit its appeal to a select few.

2.3 Wood

Wood sheets are readily available at local home improvement stores in a wide variety of species. An oak or a maple cabinet grade sheeting with different stains would certainly provide an aesthetic appeal and are easy materials to use in construction. Small half inch sections are available for cabinet construction and can be formed and resized to our specifications. For the aforementioned reasons, a wood case design was chosen for our product. Simple wood glue and finishing nails can be used to construct the clock. Holes for buttons can be milled to any specification and mounting hardware such as standoffs for the PCB can be drilled directly into the case. The only drawback to the wood design is that it is flammable. As the system is low power and DC only these concerns are at most minimal. In order to limit the risk of fire, ventilation shafts and plenty of open air space can be provided within the enclosure. Adequate heat sinks on the required components and if necessary cooling fans could also be installed although this should not be required. The alarm clock system also has a battery backup in which the battery is internal to the clock. The access door is a simple plate attached with four small screws. A sample design is provided in figure 2.1.3.1.

The system also has an external interface for the USB flash module and external plugs for external sensors. The plugs are modular allowing for the two digital interfaces for the pressure sensor and the PIR sensor. The plugs will have different adaptors for both of the sensors to prevent the end user from inserting the wrong type of adaptor. A single female two pole receptacle will pass through the case to power all internal devices. A grill was created on one of rear for vent for the speaker output. Since stereo speakers were not implemented, the two grill plates were not created. Instead the single speaker was placed directly below the LCD and is covered with mesh netting.

Figure 2.1.3.1: Sample Clock Case Design

There are five buttons on the top and a hole for the OLED screen in the front. The LCD screen has mounting holes built directly into the PCB and is screwed directly to the front face plate. The buttons may require straps through the terminals to hold them in place. Another option would be to make the top plate a little thicker ad counter sink holes to hold the buttons and pass the wires through. In order to make the buttons visually appealing, wood buttons are overlaid and glued to the off the shelf plastic buttons. A potentiometer is placed on the left plate to tune the FM tuner to a desired station.

The cost of a wood enclosure is second to ABS in expense for material in the alarm clock design. Suitable plastic ABS enclosures range in price from $6.50 to ~ $20.00. Wood and Lucite are difficult to estimate based on possible errors that would require extra materials. Assuming no errors in construction, a single piece of ½ inch 4’x4’’ cabinet grade oak or maple would be sufficient. The cost for this piece of wood is around $10.00. The glue and nails would add on an extra $5.00.

3.0 Microcontroller

3.1 Technical Objectives and Specifications

3.1.1 Goals

The microcontroller is the core component of any embedded system and it is vital that this device be chosen with care. It must meet all the system requirements and as well be affordable in regards to the physical device and the development costs.

The main microcontroller will interface all of the devices within the alarm clock (figure 3.1.1.1). This includes any sensors such as passive infrared sensors

(PIR) and/or pressure sensors, the real time clock, the MP3 decoder, the XBee module, and the . The microcontroller must accomplish the extensive interfacing and be capable of quick responses for the event driven functions.

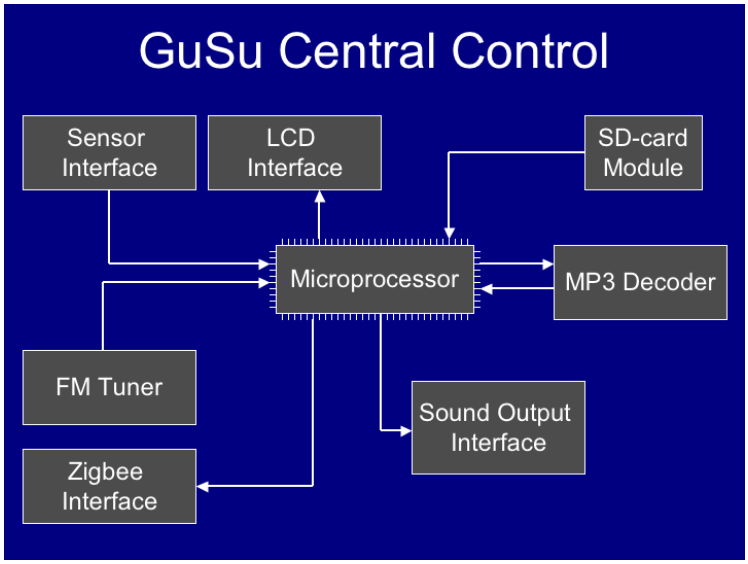

Figure 3.1.1.1: Microcontroller Interface Block Diagram

3.1.1.1 Input/output

For the PIR sensor module, the microcontroller must have a single digital input pin. Since the PIR sensor module is analog, only a single analog input is required to monitor the status. Power and ground are also transmitted to the external PIR sensor. The pressure sensors is also an analog sensor with a single input and a single output and requires two pins for each sensor. It connects through a voltage divider network as this provided more precision than measure the actual resistance through the sensor. The graphical LCD the group has chosen uses UART as does the XBee module so these two devices will need use two separate UART pin sets. The MP3 Player and the Real time clock interfaces are over SPI which is a shared port so the system uses only one set. There is also a minimum of five buttons for the user interface and each of these uses a single digital input.

3.1.1.2 Power

To simplify circuit design, devices were sought out which operate in similar voltage ranges. The common range between devices is 3-5 volts but some components require more so a voltage regulator will be necessary.

3.1.1.3 Software

Since there are devices communicating wirelessly to separate microcontrollers the system architectures are similar to aid in design. The ability to use the same

code for both microcontrollers will reduce the amount of code, which decreased the time it took to develop the software, as well as debugging and maintenance. Specifically, the selected microcontroller must have an Integrated Development Environment (IDE) available for it which allows for programming in the C or C++ programming languages. In addition to a common programming language, the control panel and the microcontroller use the same bit architecture.

3.1.1.4 Physical Package

Both of the microcontrollers are installed on single sided printed circuit boards. Each of these devices are hand soldered to the boards. In order to make it easier to mount and solder the microcontroller, all components use a dual in-line package (DIP).

3.2 Research

After taking into consideration all of the requirements, the range of choices for the microcontroller were narrowed down to two types. The first choice was from the Texas Instruments MSP430 microcontroller family. The second choice was the Atmel AVR line of microcontrollers. The choices were limited to these devices because of the access to both of the development kits for these, as well as some experience in developing code for them.

3.2.1 Texas Instruments MSP430

The first and foremost problem with the MSP430 is the availability in packaging. Texas Instruments provides a wide variety of chips in MSP430 family. The only problem is that they are all only available in a TSSOP and QFN packaging. The preferred package type is DIP. The group chose to explore the option of using the MSP430 with QFN adaptors or sending off PCB and microcontroller for soldering. The specific device investigated for the project was the MSP430F2274IRHA. The reason for choosing this device is that it met all of the requirements excluding dual UART ports and Texas Instruments currently sells a development kit which is integrated with a ZigBee module using this chip. The device features a 16-bit RISC CPU, 16-bit registers, and constant generators for code efficiency. Wake up time from the 5 low power modes is less than 1 µs. It has two built-in 16 bit timers, a single UART module, 10-bit A/D converter, and two integrated operational amplifiers. It also supports SPI and I^2C interfaces. There is an internal low power oscillator which operates at 32 kHz and built in support for an external RTC. There are 32 I/O pins available. In order to use this microcontroller the group would have to investigate the use of another LCD. With 32 I/O pins available, the LCD could easily be supported using TTL logic instead of the UART interface. Although, controlling a graphical LCD with TTL logic may add another degree of complexity to the project. The MSP430 operates at 1.8 – 3.6V which is the same voltage as the XBee radios.

3.2.2 Atmel AVR

Atmel manufactures 8 bit microcontrollers under the brand ATmega. This microcontroller is a high performance, low power consumption, 8 bit RISC microcontroller [5]. This chip is an ideal candidate for embedded applications since it is well supported by both its manufacturer and the market. They offer multiple devices with program memory in the range of 4 - 256 Kb, data memory from 256 – 2048 Kb, and packages which range from 28 - 100 pins. The ATmega can operate at as high as 20 MIPS at a clock rate of 20 MHz although the system is using a real time clock with timers; the chip also has the counters for use in embedding timing functions. Both internal and external interrupts are supported which will allow event driven communication over ZigBee and sensor monitoring. The required voltage supply can be anywhere from 1.8 to 5.5 volts with a current drawing between 250μA to .1μA which falls in the range of other modules within the system. This will lower costs by lowering costs in power system design. ATmega also support boot loaders which will permit remote upgrading and there are also multiple resources available online for working with Atmel chips and they are inexpensive. Development Software is also provided free of charge.

3.2.2.1 Input/output

There are multiple members of the Atmel mega family of microcontrollers that have at least 20 input/output pins, two serial interfaces and an SPI interface. The maximum frequencies supported by these chips ranges from 4MHz to 20MHz.

3.2.2.2 Power

As illustrated in Figure 3.2.2.2.1, the operating voltage for all of the chips is either 1.8V-5.5V or 2.7V-5.5V. The difference in minimum operating voltages varies depending on the chip selected. The Atmel AVR microcontrollers include a 32 kHz crystal oscillator for use during Power Save mode. This lowers the current consumption during Power Save mode down to 650nA. Since the appliance module will not be running continuously, the microcontroller is able to be placed in power save mode and have wake up events based on button presses or randomly to check for new information from the alarm clock

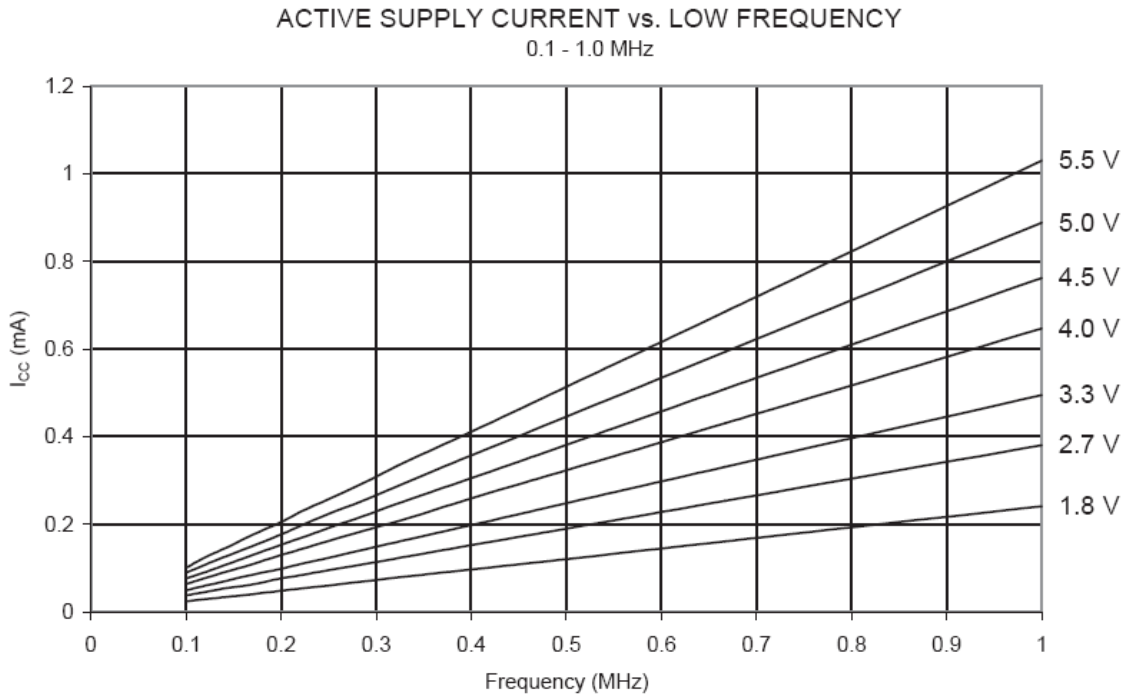

Figure 3.2.2.2.1: Supply Current Requirements
Reprinted with permission Atmel [5].

3.2.2.3 Software

Atmel provides a free IDE that can be used for writing and debugging applications written for all of its chips. The IDE is also used to compile and flash the microcontroller. It also includes a simulator that can be used to aid in application development and testing. It allows for program writing in C, Pascal, BASIC, and assembly. There is also an open source IDE called Arduino/Sanguino [6] [7]. It enables descriptive coding and simplifies the programming. The boot loader is compatible with both the ATmega164 and the ATmega644P. Atmel's IDE and Arduino's both have extensive support available online.

3.2.2.4 Physical Package

Both megaAVRs are available as dual inline packages. This makes these chips good for use in the project because soldering these chips can be done by hand, rather than being sent out. This will keep the cost of using these particular chips low and ease prototyping.

3.2.2.5 Summary

All of the Atmel megaAVR microcontrollers meet the specified minimum project requirements. The availability of each chip as a DIP is advantageous, which will

keep the cost of using them low. Since there are multiple free choices for IDEs, software development costs are also very low.

3.3 Implementation

Based on the information in the research presented in section 3.2, an Atmel microcontroller was selected for use in this project. Atmel site lists three ATmega AVRs which met our requirements for the clock and nearly all of the chips are compatible with the specifications for the appliance module. For the clock, the ATmega644p was used due to the fact that is widely supported by Atmel and by the open source Arduino boot loader. As anticipated, the memory required for the clock unit exceeded 25 KB and necessitated the use of the larger Atmega644p. The ATmega168 has 12KB of flash memory available, and was sufficient, for the appliance module. The use of a different chip did not require much additional effort because the software written for Atmel microcontrollers can be recompiled to be used in any other Atmel microcontroller. Since the size of the software for the microcontroller did not exceed the maximum flash memory size of 64Kbytes available in the megaAVR line, then expanding the flash memory using an external chip was not researched. The pin configuration of the ATmega644p (figure 3.3.1) is shown below.

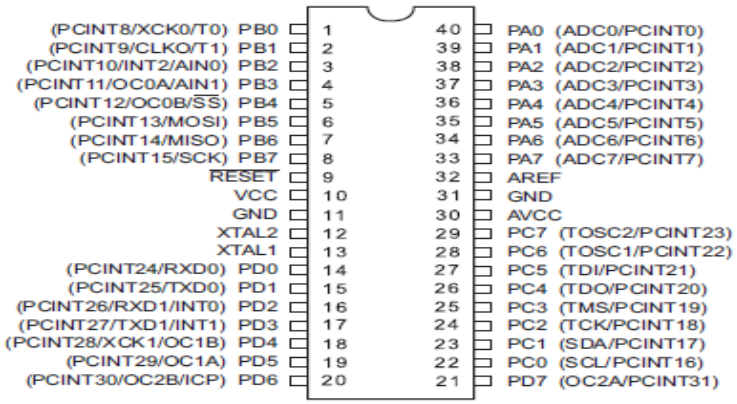

Figure 3.3.1: Pin configuration for ATmega644p.
Reprinted pending permission from Atmel.

The microcontroller is managing all of the devices within the alarm clock system. It also handles the control of the appliance module over the XBee radio modem and the detection of the remote sensor unit. Table 3.3.1 outlines all the required pin assignments for the interconnections between all secondary control modules. The location of the pins on the ATmega is in figure 3.3.1.

Device	ATmega644P	Device Pin
MUX	Pin 1 (D0)	Pin 5 (MP3 Control)
MUX	Pin 2 (D1)	Pin 2 (FM OUT)
Buzzer	Pin 3 (D2)	Power Buzzer (BZCTRL)
Clock - DS1307	Pin 4 (D3)	Pin 10 (CE/CLKSS)
Clock - DS1307	Pin 6 (MOSI)	Pin 13 (SDO/CLKXMIT)
Clock - DS1307	Pin 7 (MISO)	Pin 12 (SDI/CLKRX)
Clock - DS1307	Pin 8 (SCK)	Pin 11 (SCLK/CLKSRL)
Clock - DS1307	Pin 12 (XTAL2)	Pin 15 (32 KHz/Clockout)
MP3 (Data) - STA013	Pin 5 (D4)	Pin 7 (BIT_EN)
MP3 (Data) - STA013	Pin 7 (MISO)	Pin 5 (SDI)
MP3 (Data) - STA013	Pin 8 (SCK)	Pin 6 (SCKR)
MP3 (Control)		Pin 3 (SDA)
MP3 (Control)		Pin 4 (SCL)
LCD	Pin 14 (RX0)	Pin 5 (LCDRX)
LCD	Pin 15 (TX0)	Pin 3 (LCDXMIT)
XBee	Pin 16 (RX1)	Pin 2 (DOUT)
XBee	Pin 17 (TX1)	Pin 3 (DIN)
Button - up	Pin 35 (D26)	Button
Button - Down	Pin 36 (D27)	Button
Button - Left	Pin 37 (D28)	Button
Button - Right	Pin 38 (D29)	Button
Button - Select	Pin 39 (D30)	Button
PIR	Pin 40 (D31)	Digital Out

Table 3.3.1: Pin Assignments for ATmega644P

3.4 Testing

This included testing of the sleep function, sending data serially, and receiving data serially. The sleep function was tested by programming the microcontroller with a simple application that will put it to sleep and wake it up after a given amount of time. During this test, an amp meter was used to monitor the amount of current being used by the microcontroller. The results from the amp meter reflected the appropriate values expected from the calculations in the power section. The sending of serial data was tested by using the development board serially linked to a computer (main panel). A simple test application was written and programmed into the microcontroller that repeatedly sent data serially out of one of its ports. A terminal on the computer monitored the port and output what it received over that line. If the data received by the computer matches the data sent by the microcontroller, then the test passes, otherwise the test fails. The receiving of serial data was tested by using the development board serially linked to a computer. The computer sent data serially, and using the Arduino monitor the data was confirmed. Specific keys were transmitted and confirmed from

alarm clock system and the computer interface module. If the value matches the data sent by the computer, then the test passes, otherwise the test fails.

4.0 Alarm Module

4.1 Block Diagram

The alarm module consists of an FM tuner, an MP3 decoder, an USB Reader, an audio amplifier, a speaker, and two buzzers. The microcontroller controls the power to the FM Tuner and both buzzers, and controls the MP3 Decoder. A block diagram of the Alarm Module is shown in Figure 4.1.1.

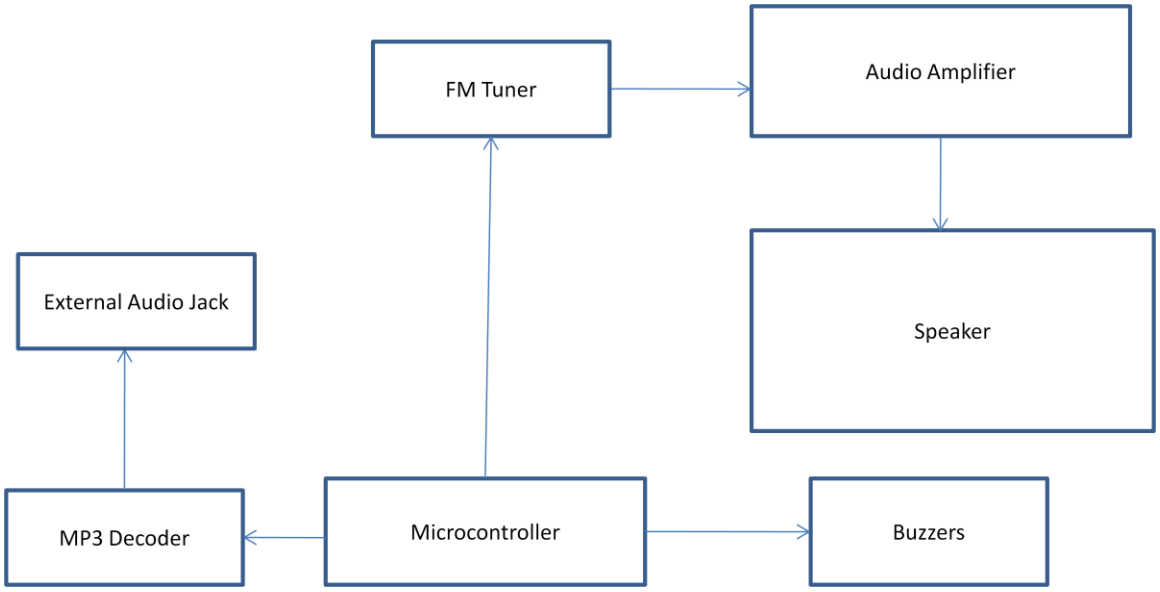

Figure 4.1.1: Block Diagram of the Alarm Module.

4.2. Design Requirements

4.2.1 Audio Output

There are two standard buzzers for the clock that can be used. The microcontroller is in charge of selecting which output (mp3, standard buzzer alarm, or the FM radio) will be accessed.

4.2.1.1 Standard Buzzers

Some small amount of research was needed to be done for the common alarm buzzers. There are several different types, but most of the common ones use a

DC voltage input and output a buzz. Each of them offer different levels of sound output, measured in decibels (dB). 90 dB should be safe for use of under 8 hrs, and 85 dB and under would be safe for much longer (it is an exponential relationship) [8]. As such, the alarm buzzer could easily exceed 85 db without causing hearing loss as it would only be on for a short time.

A quick search on Digi-key.com showed many different buzzers. A 5mm 2.8 kHz PCB buzzer with sound output of 85dB minimum was found (part number CEM-14R06CT) for $1.24 each. It runs on 40mA. A problem with this model is that it requires 1.0V to 1.7V DC, which is not in the final design for the clock. Of course, a step-down could have been used to achieve this voltage, but it was not necessary, so it was simpler to avoid that. Further searching found a 12mm (slightly larger) 2.3 kHz PCB buzzer with a sound output of 85 dB minimum and a maximum current of 30mA. This was the WST-1205S, manufactured by Soberton Inc. It requires a supply voltage of 4-6V, which is ideal for this clock. It costs $1.81 each at Digi-Key.com. A second one was found that fit our specifications nicely, and this was the CPE-503. It runs on 5V, and delivers 95dB output. It cost $3.46 each at Digi-key.com.

The buzzer is activated whenever a voltage is passed through it. Because of this, the microcontroller passes the 5V whenever the buzzer is needed. A schematic of the buzzer is shown in Figure 4.2.1.2.1, and the 5VM is controlled by the microcontroller.

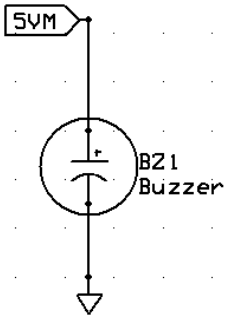

Figure 4.2.1.2.1: Buzzer schematic.
Schematic was made using ExpressSCH.

4.2.1.2 Audio Amplifier

Once the output is chosen, the audio needed to be amplified. This is done by a simple non-inverting setup of an Op-Amp (operational amplifier). The most common Op-Amps used are the 4558 or 1458 models, which are available for roughly $0.29 to $0.49 each. There are many different brands of these, but they are all of the same utility. The gain would of course be dependent on the desired audio output, and on the audio inputs. The gain cannot be large enough to saturate the Op-Amp, though, which would occur around 10 or 11 V if the Op-Amp was biased at 12V. Figure 4.2.1.2.1 below shows a basic non-inverting Op-Amp biased at +-12V, with a gain of 100. This gain was found using basic electronic formulas learned in EEL 4314, Electronics 2. The equation for it is

Vout = Vin * (1 + (Rf/Rin)) = 10Vin. Gain is defined as Vout/Vin, so would be equal to 10.

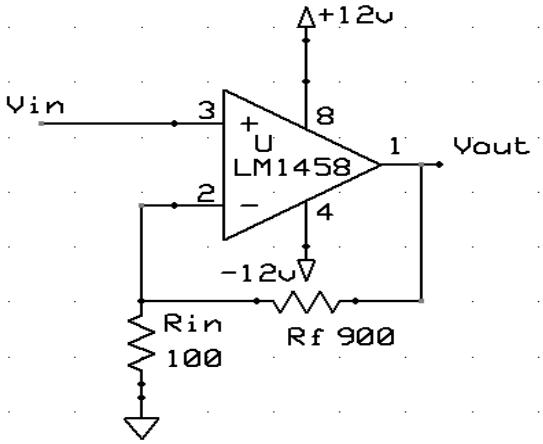

Figure 4.2.1.2.1: A non-inverting Op-Amp with a gain of 10. This schematic was created with ExpressSCH.

A problem existed, however, with using a + and – power supply. At first, the group planned on using a +12V DC power supply that is converted to the various necessary voltages, i.e. 5V, 3V, etc. However, there are no plans to have a -12V line. There do exist Op-Amps that can take a positive DC voltage and ground, with no negative DC voltages required [8]. However, these Op-Amps can only amplify an AC signal with only positive values (any negative signals are eliminated). For obvious reasons, this will not work as an audio amplifier, as audio signals use both the positive and the negative sides of the signal.

There are workarounds to this obstacle. Using one battery, it is possible to 'trick' the Op-Amp into being biased as both a positive and negative bias. This can be done by using a voltage divider, with equal resistor values, and grounding the zone between the two resistors [8]. For example, if a 12V battery were used, there would be considered a +6V and -6V on either side of the battery, biasing either side of the Op-Amp, if the circuit in Figure 4.2.1.2.2 were used. The problems with this approach, however, are twofold. For one, the range of the Op-Amp will be limited by the + and – 6V. This shouldn't be a real problem in this group's example, however. This bigger problem is that the load of the Op-Amp will be in parallel with the resistors. So if the negative or positive biasing of the Op-Amp draws more or less current (which will be the case for most of the time of operation), it will offset the loads, making them not exactly +6V and -6V. Depending on the operations, it could be +5.7V and -6.3V at times, and other variations at other times. This likely would also not have too large of an effect on this project, although in general it is not a heavily recommended option to use for biasing.

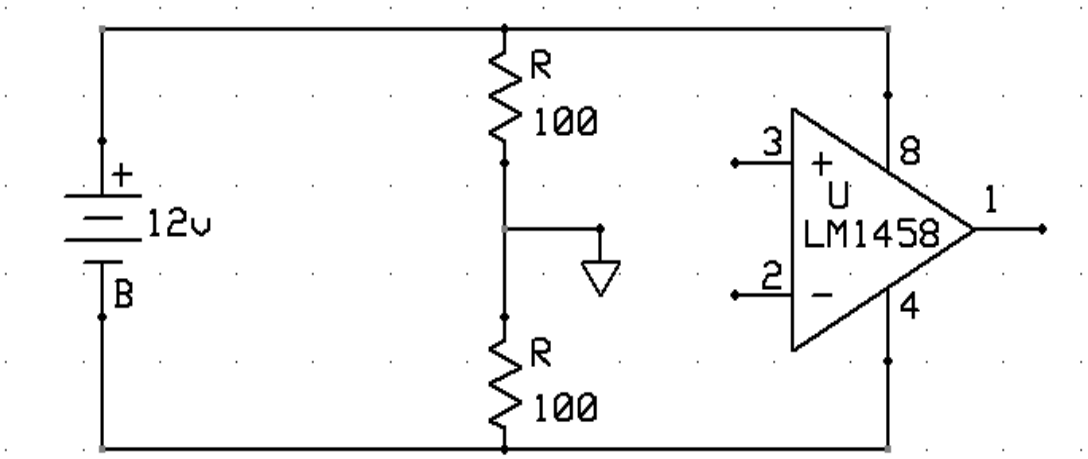

Figure 4.2.1.2.2: 'Trick' for biasing the LM1458 Op-Amp. The top rail voltage would be +6V in this example, and the bottom rail would be -6V. Schematic created with ExpressSCH.

Because there will already be a 12V power rail, however, the simplest method (if another battery would have to be used anyways, as in the above 'trick' method) would be to simply use another 12V battery. This battery would just be upside down (positive terminal to ground, negative terminal to the negative biasing of the Op-Amp). This is a good method in that the range will be from roughly 11V to -11V, which should be more than ample in this project. The downside, is that it would require another battery that would need to be replaced over time, in order to keep the Amplification, and thus the point of the clock, running.

Finally, we settled on another option. This was a DC/DC converter (NKA1212SC from Murata Power Solutions) a simple IC that takes a positive 12V input and outputs -12V. Of course, the current through it is limited and it isn't too efficient, but because it will only be used to bias the Op-Amp these are acceptable limitations. The final schematic for the audio amplifier to the speaker, that will be used in this project (using the LM1458 Op-Amp), is shown in Figure 4.2.1.2.3, along with the DC/DC Converter. Refer to section 9 which details the GuSu alarm's +12V line being used. The audio input is coming from the FM Tuner, Mp3 reader, and standard alarm buzzer. Though the resistor values are listed to give a gain of 10, Rf is actually controlled by an analog potentiometer inside the clock. The volume has to be set ahead of time, and cannot be changed during alarm time without the user taking apart the case. This was done so that the sound output can be set by the user, but only when setting the alarm.

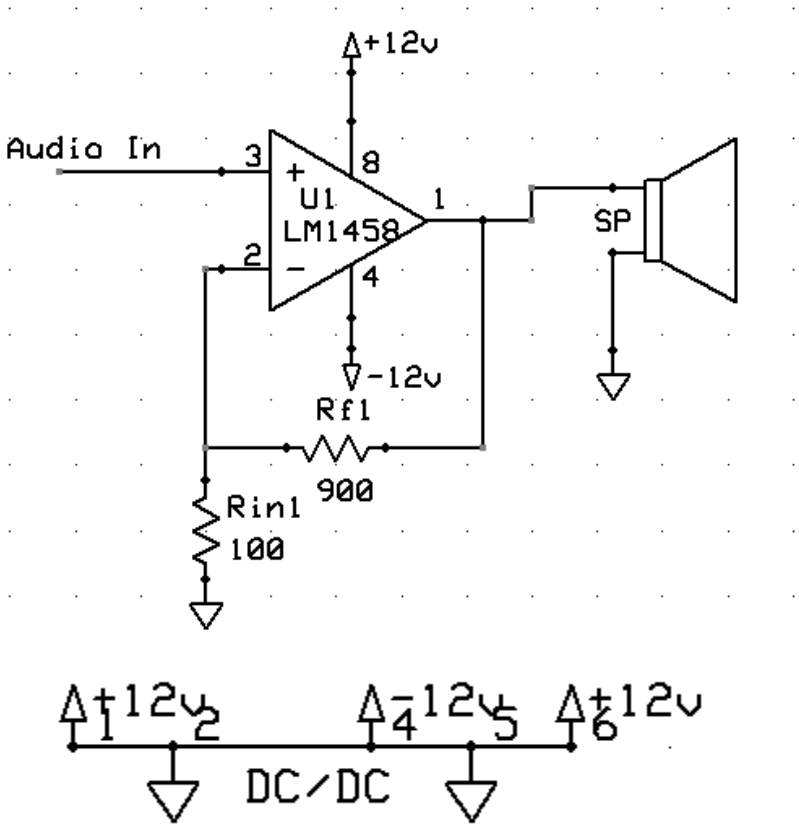

Figure 4.2.1.2.3: Audio Amplifier Module final schematic.
The Audio In will be controlled by the microcontroller.
Schematic created with ExpressSCH.

After assembling the device and testing it, it was found that the audio was not amplified quite enough for the internal speaker. So an alternate design implementation was undertaken. The output from the Op-Amp was split with one line going to the main speaker and the other line going to an external audio jack that was taken from an older speaker. This jack was placed on the back side of the case, and allows the user to plug in external speakers that can amplify the signal much louder. The original speaker was also included just in case the user would just unplug the speakers and go back to sleep.

4.2.1.3 Speaker

There are many types of speakers available, and through searching on Digi-Key, there were many that could fit the needs of this group. Ideally, the speaker would use a minimum of power/current consumption, output a maximum level of dB, be as small as possible, be easily integrated into the alarm clock, and have as low of a cost as possible. Of course, there are no speakers that can deliver all of those competing ideals, but a decent speaker was found by way of the Panasonic EAS-4P15SA. This speaker uses .1W max power, can output up to 92dB, has a 45mm diameter and 18mm height, terminates in solder pads, and costs $4.32

each when purchased without a bulk discount. This speaker was more than sufficient for the needs of this project.

4.2.2 FM Tuner

An FM tuner was to be integrated with the GuSu alarm clock and needed to be able to wake the user with any chosen FM radio station. This was to be in addition to the option for mp3 audio from the on board SD card slot and standard alarm beeping. It was intended for the device to use a minimum number of parts, and the radio needed to be able to be tuned by the user to any local station that has strong enough of reception to be easily picked up. In this case, that would be all FM stations that are broadcast from the Orlando area. The tuning needed to be relatively easy for the user to do; with a user interface on the outside of the alarm clock housing unit allowing access to change the stations. This could be done with an analog knob or two buttons, depending on the method of reception. The radio needed to be able to tune at every 200 kHz frequency interval from 87.5 MHz to 107.9 MHz, which is the frequency range for broadcast FM radio in America. It was also important that the radio is properly selective.

4.2.2.1 Research

The process of integrating an FM Tuner into the clock began with identifying the various alternatives that are available. Through researching online, it became apparent that there were two main ways to do this. Several circuits could be built from scratch and connected, or a partially or completely prebuilt receiver could be purchased.

There are many different circuits that could be built from scratch, from a (somewhat) simple single transistor receiver to more complex super heterodyne receiver circuits. The most common radio receiver today (and it has been for well over 50 years) is the super heterodyne receiver (short for supersonic heterodyne receiver) [9]. A block diagram of the important elements of this receiver is shown below in figure 4.2.2.1.1.

The RF input, received from an antenna, is fed through a filter (the Preselector Filter) to severely limit the frequencies passing through to a narrow band including the frequency that is wanted. The Limiter acts similarly to a surge protector; if a seriously high powered signal were to come through the RF input, this limiter would protect the LNA (Low Noise Amplifier). The Switchable Attenuator is able to, as needed, slightly reduce the strength of the signal if it is strong enough to saturate the LNA. Next, the LNA amplifies the signal, though it is important that it is not damaged by too much power hitting it. Any damage done is permanent. The amplifier's purpose is to amplify the main signal to a point where it is further distinguishable from the background noise). The Image

Filter reduces image noise, and the Mixer converts the RF signal to an IF (Intermediate Frequency) signal.

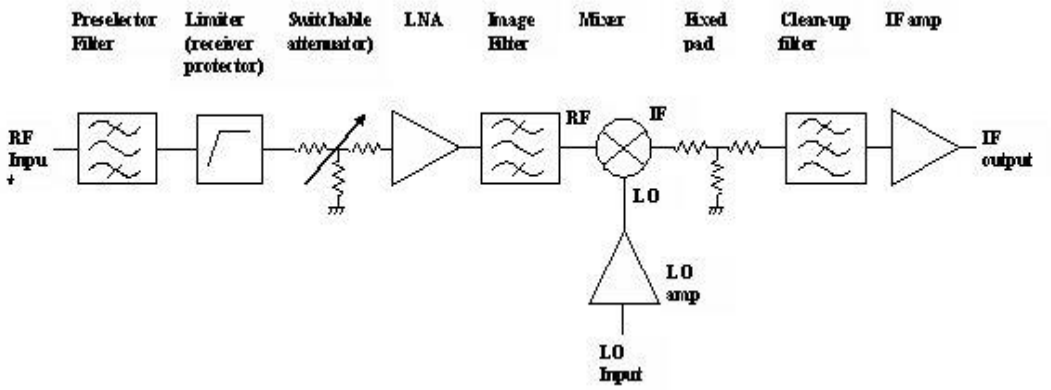

Figure 4.2.2.1.1: Block diagram of a common super heterodyne receiver. Reprinted with permission from Microwaves101.

This is the main advantage of the super heterodyne receiver. The IF signal is at a much lower frequency than the RF signal, and thus, can be modified with lower-frequency components. It is much 'cheaper' to add gain to IF signals (and lower frequency signals in general) than higher frequency signals. It is also easier to be more selective with the lower frequency signal [9]. After being mixed into an IF, the signal must pass through a LPF (Low Pass Filter), the Clean-up Filter to remove any remaining higher frequency signals, such as the LO (Local Oscillator) or RF. Finally, the IF Amp is used to amplify the signal to its final level. Again, this is much cheaper to do after modulation than at its higher-frequency state.

These circuits would not have to be fully implemented on a PCB. There are ICs available that consist of regenerative FM receivers. The most common one over the last 20 years may be the Phillips (now NXP Semiconductors) TDA7000. This IC is a basic FM receiver, with only mono audio output (which would be acceptable according to our one-speaker specifications), and selectivity decided by the local oscillation frequency, which would be determined by a small variable RC circuit. The TDA7000 were no longer produced beginning in December 2003, although they are still available on the market. There are also two later models, the TDA7010 and TDA7021. An example of the block diagrams of the TDA7010 is shown below in figure 4.2.2.1.4.

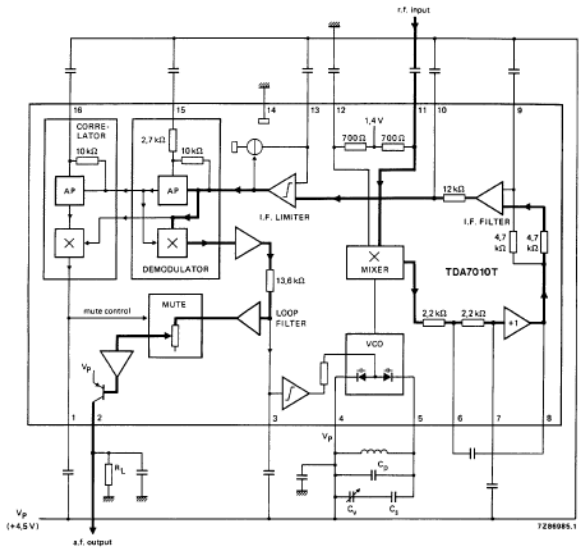

Figure 4.2.2.1.4: Block diagram of the TDA7010.
Reprinted with permission from Digi-Key.

This circuit could be implemented on a PCB board more easily than the “do-it-yourself” method, but would eat a lot of space and use a lot of components (though the space and components required are minimal comparatively). The variable RC circuit for tuning could also present some problems. One of the goals is for easy user frequency selectivity, and requiring the user to adjust a potentiometer would qualify as such.

The second main option available would have been to purchase a prefabricated chip that includes the FM receiver. These are generally digital circuits that can be controlled by a microcontroller to receive the desired station. Most of these circuits require external elements, although some are complete receivers in one integrated circuit. There are many different companies that offer varying solutions to this problem.

Sanyo is one of such companies. They have a line of FM receivers from the LV24000 series. These are all one-chip tuners, requiring minimal external components [10]. Some of these chips even include internal antennas. These tuners also have the ability to include RDS (Radio Data System). The RDS system allows for the output of the name of the station/song and band that is playing. One nice thing about this line of chips is their versatility; they have many different features available on different chips. Table 4.2.2.1.4 shows the different tuners in production and their feature sets, as they would be applicable to the needs of this project.

Having the AM tuner would have been a nice bonus, though it was not necessary to this project. While any true commercial release of a project like this one would doubtlessly need it, FM is generally listened to much more often by most younger people. Especially since the function of our alarm is to wake the user up; a loud rock song would do the trick much faster than a talk show or news station (the

kind of shows that are found more frequently on the AM band). The RDS decoder would be handy, though also most definitely not a necessity. The user knowing the name of the song that is playing is of less importance than the actual waking up. RDS functions would have more necessity in systems where the main function is to listen to and enjoy the music/programming. Most of the LV24000 lines of chips are 3-wire controlled, but the couple that are I^2C is noted. The headphone amp is not truly needed either, because another audio amplifier is used elsewhere in the GuSu system.

Model #	+AM Tuning	+RDS	I^2C Controlled	+Headphone Amp
LV24003				X
LV24010		X		
LV24100	X			
LV24230			X	
LV24233			X	X

Table 4.2.2.1.4: Sanyo FM tuner one-chip solutions [10].

Sanyo was contacted via email, and they were very helpful. They provided help with locating the part in the event that the group had decided to go with it, and they also gave important documents such as the datasheet, access to their LV24230 'Easy Radio' schematics and information, and offered to help however they could during the process.

Another company worth looking into was Silicon Labs. They also have many FM tuners on the market, most notably their line of Si470X ICs. These receivers do require external components, although the amount is minimal. Each model, like the Sanyo receivers, has different feature sets. The Si4702 and Si4703 models offer full FM receiving, with the Si4703 model including RDS decoding. The Si4704 and Si4705 models improve on the previous versions with Bluetooth capability, and will accept transmissions in that format. The 4705 chip also includes the RDS decoding. The Si4708 and Si4709 chips improve on those by decreasing the size to an amazing 6.25 mm^2, again with the Si4709 including the RDS decoding. An example of the Si4704/05 models (with necessary components included) is shown below in figure 4.2.2.1.5.

These models all seem to be difficult to order just one of; most of the authorized retailers require minimum purchases of over 2500 parts. Digi-Key had none available of any of the above models. Avnet Memec had only the Si4709 and the Si4703 part readily available, for $13.75 a piece. Nu Horizons had none of the above, and Mouser Electronics had the Si4704 for $9.21.

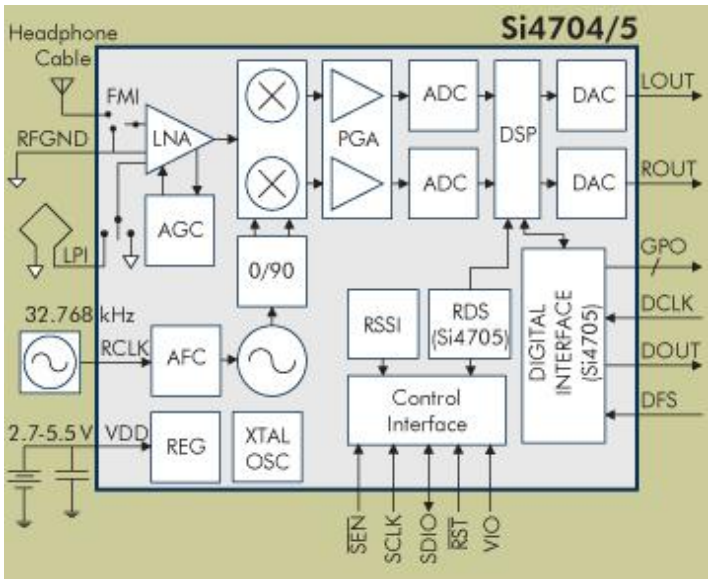

Figure 4.2.2.1.5: A block diagram of the Si4704/05 FM tuner. Notice the few needed external components. Reprinted with permission from Silicon Labs.

Silicon Labs was similarly helpful when contacted about the group's project. They responded promptly to emails, and their local sales liaison quickly replied with the datasheets, latest device errata, tips for PCB layout, and information on the embedded antenna.

A third option that could have been possibly implemented would have been from Silicon Labs as well. This project did not support a USB reader. If that had changed, Silicon Labs does manufacture an FM Tuner that is embedded into a USD card [11]. This looks to be used mainly for computer operating systems using their software to decode and play the music; however, it is reasonable to assume that it could be controlled with the microcontroller in this project.

4.2.2.2 Implementation

It was originally decided to use the Si4704 FM tuner. This was picked because it was cheap, small, and easily integrated and controlled. One was found on www.mouser.com for $9.21. It was ordered, it came in, and the group was very surprised as to how small it was (although it was exactly as advertised, 3mm X 3mm). It also came with no pins, and apparently needs a special machine to 'press' it onto a PCB. At this point, the Si4704 FM tuner was no longer a viable candidate for implementation. The Sanyo LV24000 series of FM Tuners was reinvestigated, and the same size/mounting issues remain with them. It was decided that the use of these specialty one-chip tuner chips should be left to the companies that have the abilities and the facilities to use them.

At that point, it was decided to use the TDA7000 chip. While all mainstream electronics stores (Mouser, Avnet, Digi-Key, etc.) were out of stock on it (if the

part was even listed), a few of them were found on E-Bay. 2 were purchased for $21.25 from littlediode_usa. Using resources found online, including the datasheet for it and a couple of helpful websites, the schematic in Figure 4.2.2.2.1 was created [12] [13].

As can be seen 4.2.2.2.1, there are many external components to be integrated, including 16 capacitors. The tuning is determined by three things: the input voltage, the variable coil (L1), and the potentiometer. The easiest way to set up the tuning for the user is to take the following steps [12]. First, for FM reception, the input voltage should be around 4.5V to 5V (5V will be used, as it is a common voltage level through the alarm clock). Next, the variable coil should be used to tune to the upper (or lower) frequency. In the case of FM reception, that would be 108 MHz (or 88 MHz). Finally, the potentiometer can be used to fine-tune the frequency between the specified ranges. This potentiometer also does not need to be attached directly to the PCB; it could be attached to the casing of the alarm clock with wires going to the PCB to be soldered on. This would allow the user to change radio stations without opening the casing.

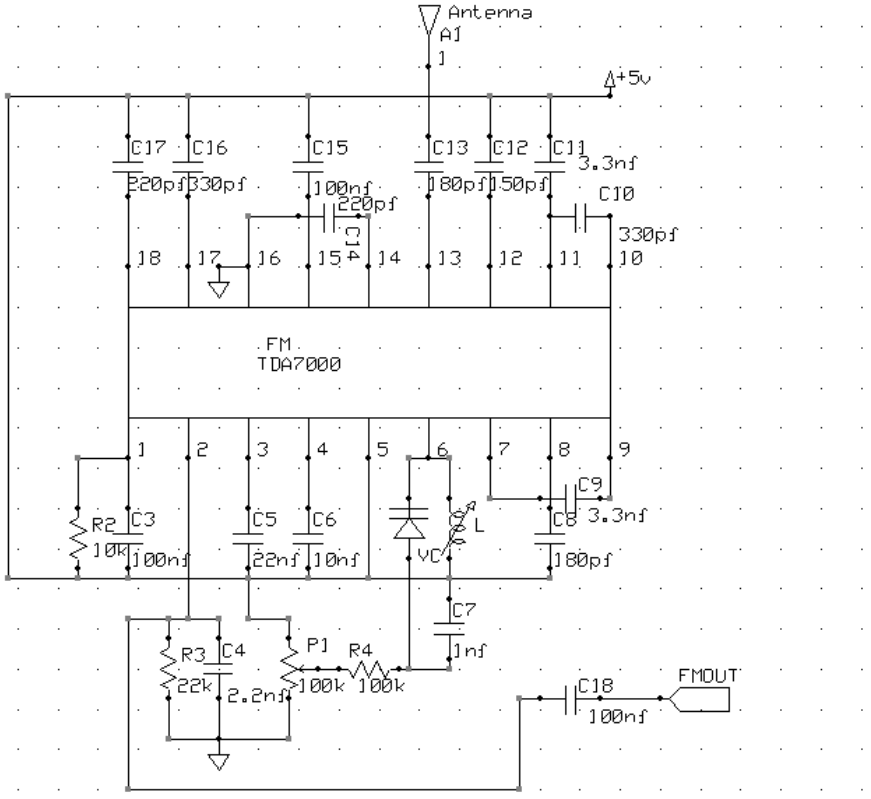

Figure 4.2.2.2.1: Final design of the TDA7000 FM Tuner implementation. Schematic created using ExpressSCH.

The antenna A1 can be built a couple of ways. Ideally, the clock will not have any exterior antennas. An interior antenna can be used that is at least 10 cm long, and to be on the safe side, a longer one will likely be used. Another

important criterion would be a lack of interference, and one other component in the clock could cause some serious interference: the Zigbee device. Because of that, the FM tuner and the Zigbee device should be placed on opposite ends of the PCB, and the antenna for the tuner should stay on that end of the clock.

The audio output level of the TDA7000 is about 75mA. This is amplified by the audio amplifier, as needed to produce an optimal loud noise. The power signal is supplied by the multiplexer when the FM tuner is selected by the microcontroller.

4.2.2.3 Testing

The FM receiver was tested on its own breadboard first. It was powered, and connected to an amplified speaker. While there were initially problems with the variable inductor, the group got the device working and were able to select from the major radio stations in the area. The selectivity was extreme, however, although it was somewhat helped by including a 50k resistor in series and a 100k resistor in parallel with the 100k potentiometer. This was because all the stations were located in the upper 50k of the potentiometer range.

4.2.3 MP3 Decoder

To accommodate user comfort and preference, the Get Up Stay Up (GuSu) Alarm System has the ability to read and play MP3 files as audio output in addition to the other alarm audio/action options. This allows the user to choose any of the music or sound file they own or can create using one of the many available free and open source audio recording software as the alarm's wake up sound, greatly widening the alarm's range of available options for waking it's user. The storage of MP3 files is handled by the on board USB Flash Drive slot discussed in its own section. In order to make use of the data stored on the USB Flash Drive hardware and/or software is required in order to decode the files and process them. ID3 tags can also be handled to display the song name and artist on the GuSu's LCD screen.

4.2.3.1 Research

Due to the GuSu's architecture a software solution to handling MP3 audio playing required many hours of coding and pins that were dedicated to reading from the SD slot and passing along audio to the GuSu's speaker output, greatly decreasing the number of available pins for other uses. A hardware solution involving an MP3 decoder chip was a much more convenient and stable solution considering pins would only be required to send control signals to the MP3 decoder chip and relieve the engineers of the burden of software creation and testing. The team put a lot of effort into researching what MP3 Decoder to use with the GuSu prototype and it proved to be a difficult challenge deciding which decoder would work best with the design at hand. One of the main sources that were used in looking for MP3 decoders was Sparkfun electronics, this company

seemed to hold a large array of different types of MP3 decoders. Some other companies found on the web that carried MP3 decoders were PJRC electronics and STMicroelectronics. The following contains information on the various MP3 decoders that were considered along with their specifications and why they were or were not chosen.

Possible solutions range from lone decoder chips, to integrate-ready boards, all the way up to fully assembled boards which only require a storage device be connected. While the third option was convenient, the prices range over a $100 and would have been harder to interface with from the GuSu system without either modifying the board received or having separate controls. In addition the excess parts and components jeopardized the design plans for keeping the GuSu as small as possible. The second option did not have this problem, and parts were usually priced under $50. Below (table 4.2.3.1.1) is a table comparing some of the available MP3 mini circuit boards.

Item No./Name	On-board Chip	Interface	Output/Input	Dimensions	Price	Supplier
MINIMP3	VLSI VS1002	SPI	Microphone Audio Out	45 x 55 mm	$ 23.90	[15]
VS1003B-L SD Card Mini Player	VLSI VS1003B-L	SD card	Audio Out	N/A	80.00 €	[14]
VS1000B-L Tiny Player	VLSI VS1000B-L	USB	Audio Out	N/A	80.00 €	[14]
VS1053B-L	VLSI VS1053B-L	SD Card	Microphone Audio Out	N/A	80.00 €	[14]
MOD-MP3	VLSI VS1002	UEXT SD/MMC	Microphone Audio Out	57 x 45 mm	$ 41.94	[20]
BOB=07832	VLSI VS1002	UEXT SD/MMC	Microphone Audio Out	57 x 45 mm	$ 40.95	[21]

Table 4.2.3.1.1: Comparison of MP3 mini circuit boards

Some of these mini boards did include SD capability built in, however most used battery power, already had buttons soldered to the control lines, and included parts or capabilities not needed for the GuSu system. Another complication was controlling audio output for the system when the output lines were already connected to audio jacks and microphone lines for encoding. Extra hardware presented complications for running on battery backup during alarm time, and having unused hardware and controls sitting idle also interfered with other signals to and from the main micro-controller. Therefore, with respect to routing of audio, control, power consumption, and overall design size, the optimum solution was to integrate a lone MP3 decoder chip.

One of the first decoders looked at was the VS1053b [20]. This chip was very interesting in that it had the ability to decode multiple audio file formats and not just MP3s. Some of the file formats the VS1053b was capable of decoding were Ogg, MP3, ACC, WMA, and MIDI. The team thought this chip was a good fit for the GuSu design because of its potential to decipher the high quality Ogg sound format. Although this was a great attribute to this chip, the chip did require additional software plug-ins to handle these file formats. Some specifications for the VS1053b chip were that it was controlled via a serial input bus and had the

option of interfacing through uART for debugging purposes. The voltage supply to this MP3 decoder chip was ran at 3.6V which was in the range of voltage that was needed to be used with the GuSu Design. Another key feature that caught the team's eye was the relative low power consumption at about 50mA. After realizing that SPI was the only interface with this MP3 decoder, this solution was considered a poor product due to the amount of SPI pins that would be used with the ATMega644P microcontroller. Pricing on this chip was on average about $19.95 which wasn't that pricey for the high quality of this chip. Shown in figure 4.2.3.1.1 is a schematic of the VS1053b MP3 decoder showing the processing unit on the chip as well as the interfacing capabilities.

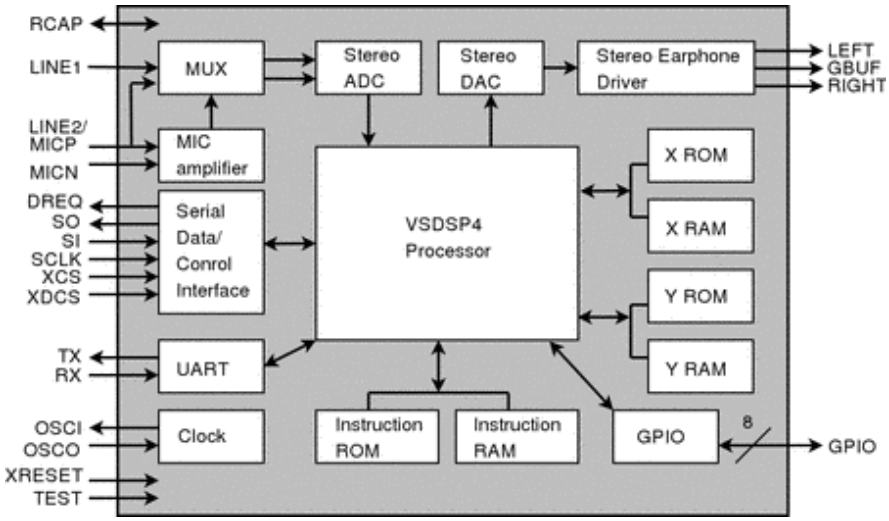

Figure 4.2.3.1.1: The package design of the VS1053b audio decoder. Reprinted with permission from VLSI Solution.

One other MP3 decoder that was manufactured from VLSI Solutions based in Finland, an integrated circuit developing company was the VS1001 [21]. This chip was also fabricated from the same company that made the VS1053b. The VS1001 chip is not as involved and does not have all of the extra features as the VS1053b but it had some of its own advantages. The main difference in this chip was that it only supported the MPEG audio layer codec whereas the VS1053b had support for multiple audio formats. One other small difference was the voltage operating range which had been considerably less than the 3.6V of the VS1053b; this chip operated at about 3.3V which was an important factor in deciding which MP3 decoder to use. Some similarities of these two chips were that they both of them had the same clock operating frequency at about 13 MHz. The main interfacing solution to this MP3 decoder was through SPI, bearing in mind this chip did not have a uART interface to use for debugging purposes. Pricing on the VS1001 averaged about $21.00; this was a bit pricey for this discontinued chip from VLSI Solutions. Once again, this solution only had SPI interface and was not ideal for the microcontroller the GuSu design used due to the constraints of the other modules that were using this interface.

Lastly, the team had found an ideal candidate MP3 decoder that worked easily with the ATMega644P microcontroller and the SD Card Reader. This chip was called the STA013 MP3 decoder developed by STMicroelectronics. The main feature of the STA013 decoder was that it could handle just deciphering of MPEG layer 3 formats, specifically MP3s. This differed from the other decoders that were researched in that the STA013 only dealt with one type of file format which made it idyllic for handling just MP3s, which are the most popular form of sound format on the market today. When decoding these formats the STA013 had a special ability to output information in stereo, dual channel, or mono sound types. The STA013 was run off of 3.3V and helped with the GuSu design because this was low voltage for a decoder. Surprisingly enough the STA013 had very low power consumption at 85mW and also a lower clock frequency than the other MP3 decoders that were researched running at 10 MHz. A key feature that caught the eyes of the team members had been the I2C interface capability. Having essentially used all of the uART and SPI interface pins on the microcontroller there were a few digital pins left for I2C interface. Pricing on the STA013 was set at around an average of $20.00 which lined up with the other decoders looked at. Since all of the decoders were about the same price and due to the fact that the team needed a device with I2C operation the STA013 was the right decoder for the price and features.

The STA013 has two modes of operation; it can work in either Multimedia mode or Broadcast mode. In the Multimedia operation mode the STA013 decoded the incoming MP3 data streams and output them to the speaker with much ease. This type of operating was controlled by buffer management that was embedded on the software within the decoder. While operating in the other mode, the STA013 received a data stream but had to check that the bit rate of the incoming MP3 data matched the actual bit rate of the stream that was being decoded. One important fact about the STA013 I2C data bus was that it would always act as a slave device instead of a master when connected to the microcontroller and speakers. Shown in figure 4.2.3.1.2 are the absolute maximum ratings of the STA013 decoder.

Symbol	Parameter	Value	Unit
V_{DD}	Power Supply	-0.3 to 4	V
V_i	Voltage on Input pins	-0.3 to V_{DD} +0.3	V
V_O	Voltage on output pins	-0.3 to V_{DD} +0.3	V
T_{stg}	Storage Temperature	-40 to +150	°C
T_{oper}	Operative ambient temp	-40 to +85 (*)	°C
T_j	Operating Junction Temperature	-40 to 125	°C

Figure 4.2.3.1.2: The absolute maximum ratings of the STA013 MP3 Decoder. Reprinted pending permission from STMicroelectronics.

Having done the research on these different decoders it seemed like the STA013 was the best fit for the implementation of the GuSu system. The VS1053b seemed like a great choice but the team only cared about the MP3 formatting of audio files. Dealing with different formats of files had proved to complicate the

design much more than it already was. Having the data interface as I2C also helped the team choose this chip over the others. Thus, this proved to be the pick for the GuSu design. The implementation of the STA013 decoder chip will be discussed in further detail in section 4.2.3.2 of the document.

4.2.3.2 Implementation

After doing much testing with the STA013 MP3 decoder it was decided to drop this component from the GuSu prototype. Reasons for abandoning this decoder are given in the testing section of the MP3 decoder. The team went back and looked into the researched MP3 decoders to look for a different one and the VS1003 from VLSI Solution was chosen to be implemented on the GuSu system.

The VS1003 is a single-chip MP3/WMA/MIDI/WAV audio decoder. On this chip is a high performance and low power DSP processor. It has the capability of decoding MPEG 1, 2, and layer 3 audio files in CBR, VBR, or ABR format. To operate the VS1003 the analog and digital positive voltage supply does not exceed 3.3V and a 12 or 13 MHz clock is used. Power consumption of the VS1003 is considerably small at only 50mA. A key feature that this decoder uses to ensure good audio output is the high-quality stereo digital to analog converter that does not allow any phase errors between channels. If no decodable data is found, the VS1003 will enter idle mode. This audio decoder has a uART interface that allows for debugging purposes when implementing software to control this device. The VS1003 is used in conjunction with the VMusic 2 device that is discussed in further detail in the SD/USB section of the document. Shown in figure 4.2.3.2.1 is the flow of data through the VS1003 audio decoder.

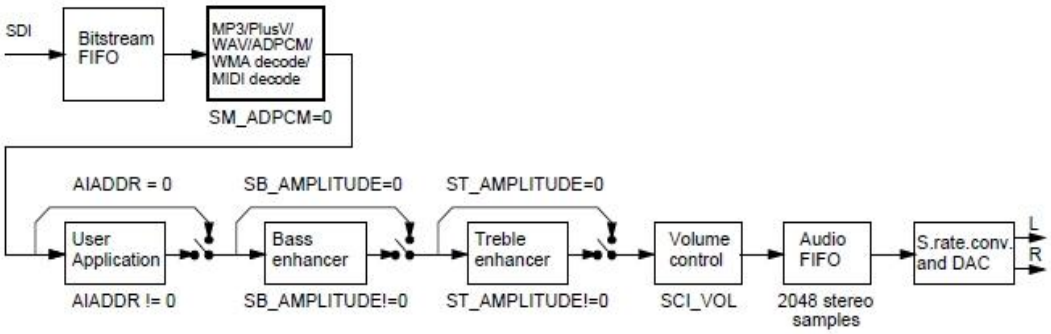

Figure 4.2.3.2.1: Data flow of the VS1003 Audio Decoder.
Reprinted with permission from VLSI Solution.

Since the VS1003 decoder is embedded into the VMusic 2 which is discussed in the SD Card/USB Drive section there is not much that the team had to implement on this device. Figure 4.2.3.2.2 shows the schematic of the VS1003 audio decoder connected to a headphone jack which is used for audio output. Once data is decoded through this device there is a left and right output connected to a phonejack stereo component. A 3.5mm audio cable will be used to connect to

this terminal while the other end of the cable is split to the voltage and ground lines to connect to the speaker. The VS1003 has the capability to check the bit rate of the MP3 data being passed through the chip and also can calculate the sampling rate of the audio data such as the MHz of each file. This chip can be powered using a 3.3V supply line, anything higher can ruin the chip. This voltage will be provided by the system's power supply provided through the step down voltage regulator from 5V to 3.3V. All of the VS1003's 48 pins will be used in connection with the USB Drive interface and headphone jack output. The main pin connections that are used will be the data out, data in, clock, and reset pins.

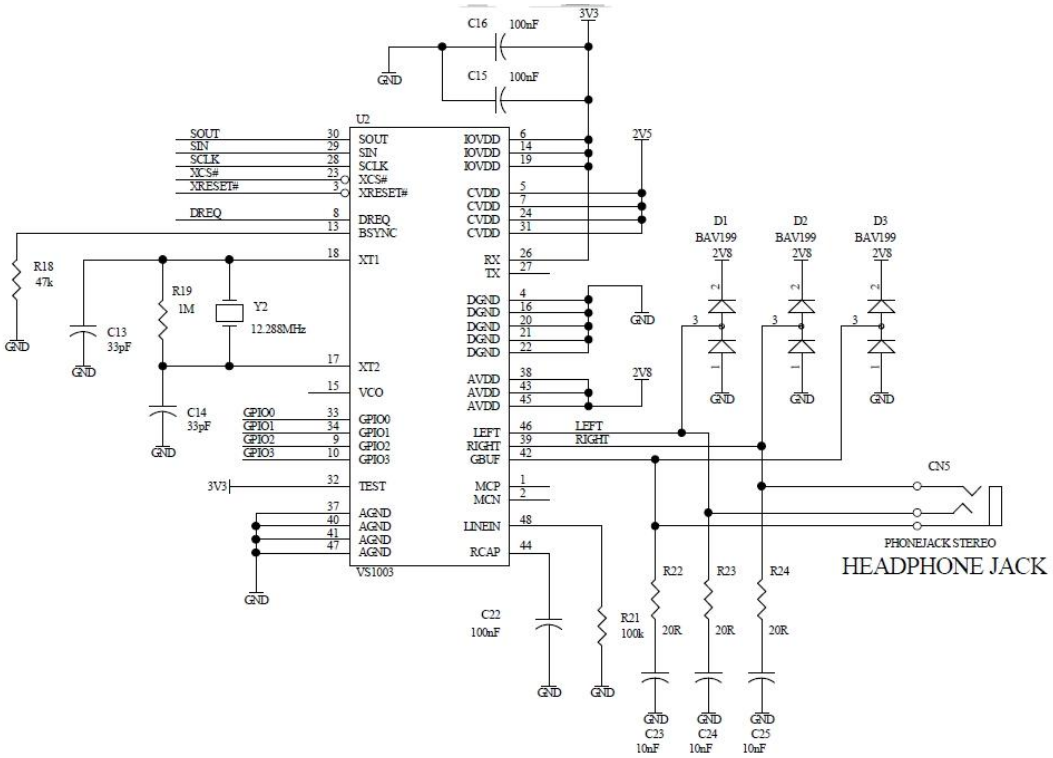

Figure 4.2.3.2.2: Schematic of the VS1003 Audio Decoder with a headphone jack for audio output. Reprinted with permission from FTDI LTD.

Moving onto the actual connections of the VS1003, in the decoder's package design there is a serial data control interface. This is where the SPI interface to the decoder comes into play. The VS1003 also has four general purpose input and output lines that can be connected to the decoder's VSDSP processor to update software or add extra functionality to this device, these coincide with pins 9, 10, 33, and 34 of the VS1003. As stated before there is a uART interface that has receive and transmit lines that can be used to debug the component in case there are errors or for testing purposes. The TX and RX pins can be seen in figure 4.2.3.2.2 on pins 26 and 27. There are many different types of resistors and capacitors that will help regulate voltages throughout this component. Data will flow through the VS1003 by receiving its input bitstream through the SPI bus which is used as the system slave. The input stream is decoded through the

various stages of the package and then is sent to a digital to analog converter that is already embedded onto the chip.

Dealing with the software to control this audio decoder will be fairly simple. Software code needed to be implemented on the ATMega644P microcontroller; the first bit of code would be used to read in data from the USB Flash drive which is connected to the VMusic 2 module. This would allow the microcontroller to control the module that contained the VS1003 and the USB flash drive reader. There would only be one function that needed to be on the ATMega644P which is the read function. More on the implementation about this chip and the module it is embedded onto is talked about in the next section, Testing.

4.2.3.3 Testing

There were many reasons that the team decided to drop the STA013 MP3 decoder. When the device came in the team immediately went to work testing its functionality on a breadboard. It was soon discovered that this device required much more implementation than was planned for. There was much trouble in finding the 14.7456 MHz crystal that it needed to operate and there were a large amount of resistors and capacitors that would have had to been used to use them on the printed circuit board. There was success in powering the STA013 by connecting it to a 2.9V voltage source and ground. There was a sample program provided in the Arduino libraries, but it was written in C code. All of the software libraries for the GuSu were being written in C++. After seeing the software to control this device it came to our attention that this component would be extremely complex to write software for. On top of these problems there were a lot of misfortunes when dealing with the SD Card reader. Finally, after time was running short with the deadline of the project approaching the decision was made to drop this component. The team went back and looked at the research that was done before and we realized that an audio decoder from VLSI Solution were ultimately the best choice. Modules were looked at that included both the SD Card/USB Drive interface and an audio decoder from VLSI. VMusic 2 included the VS1003 decoder which has the ability to decode different audio formats than just MP3s like the STA013 could do. Testing with this device was found to be much easier because the VS1003 was embedded on a printed circuit board inside the VMuisc 2 module. Powering the device included a 5V voltage source provided by the microcontroller. A simple script was written in C++ to test the functionality of the device. We were successful to get audio output from the VMusic 2. More information about the VMusic 2 is discussed in the implementation section of the SD Card/USB Flash drive reader.

4.2.4 Sim Card/USB Drive Reader

The purpose of the SD Card Reader allowed the user of the GuSu prototype to store their favorite songs and music on a widely available Secure Disk for playback through the GuSu's sound output. The reasoning behind this was so that besides the FM Tuner the user could also have a backup way of listening to

their favorite music and not just their favorite radio stations. Using this method was found to be the most secure and most updated to date. More will be discussed on how the SD card was used and how it allowed the user to listen to their favorite MP3s.

4.2.4.1 Research

The first research that was done involved deciding what kind of storage device the GuSu design would use to pass MP3 files through the MP3 decoder and to the speaker. There are many types of storage devices out on the market today. Some of the devices are Compact Flash, USB storage, hard drives and even SD cards. SD is a short acronym for Secure Digital which was developed by the Matsushita, SanDisk, and Toshiba companies. The purposes of these devices were to be used as portable solid state drives which could transfer pictures, videos, and other data. The main use of these storage devices were to be used in cameras, PDAs, and video game consoles to name a few. SD has been gaining momentum in recent years due to its relatively small size and large capacity compared to other storage mediums.

Card	Width, mm	Length, mm	Thickness, mm	Volume, mm^2	Mass, g
Compact Flash I	43.0	36.0	3.3	5108	3.3
Compact Flash II	43.0	36.0	5.0	7740	
Smart Media	37.0	45.0	0.76	1265	2.0
MMC, MMCplus	24.0	32.0	1.4	1075	1.3
RS-MMC, MMCmobile	24.0	16.0	1.4	538	1.3
MMCmicro	14.0	12.0	1.1	185	
Memory Stick Standard	21.5	50.0	2.8	3010	4.0
Memory Stick Duo	20.0	31.0	1.6	992	2.0
Memory Stick Micro	12.5	15.0	1.2	225	2.0
SD	24.0	32.0	2.1	1613	2.0
miniSD	20.0	21.5	1.4	602	1.0
microSD	15.0	11.0	1.0	165	0.27
xD	25.0	20.0	1.78	890	2.8
USB	Varies	Varies	Varies	Varies	Varies

Table 4.2.4.1.1: The relative sizes and masses of various multimedia storage devices [22].

After researching into the different types of storage devices through various websites the team decided the SD storage format would be the best fit for the design. Since all of these devices were encased into the alarm clock a solution was then needed for a permanent storage device. USB proved not to be a good choice for this because the purpose of the USB sticks was to be plugged and played as well as portable; they were also flimsy inside of the alarm clock and increased the possibility of dislodge from its connector. A computer hard drive was looked into but this would also prove to be disadvantageous. A computer hard drive has moving parts and therefore the life expectancy would be less than

that of the other solid state drives. A hard drive would also draw way too much power for the alarm clock to handle and interfacing these devices to the microcontroller or MP3 decoder proved to be very challenging. After we eliminated these devices from our design, the team found that the SD storage medium was the most advantageous for the GuSu alarm clock. Table 4.2.4.1.1 shows some different storage mediums and their relative size to one another. The actually storage capacity also varies from one to the other. Researching into the Secure Digital format showed that this allowed for the most capacity variation between the different storage mediums.

The team's first choice when looking into SD storage formats was a special type of SD Card Reader that would interface with the MP3 decoder. Researching into GHIElectronics, a company which specialized in storage mediums for embedded systems; it was found that they produced an SD Card Reader that used various interfacing connections which included uART, SPI, and I2C. This also proved useful in connecting to the MP3 decoder because this component contained all of the interfacing types.

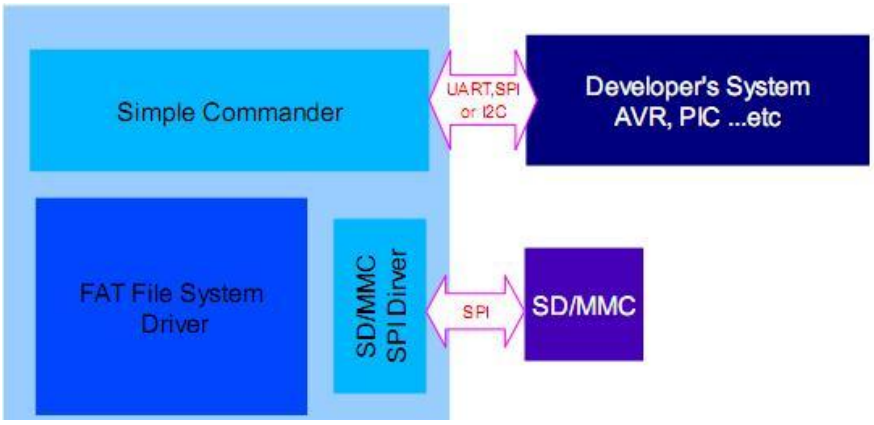

Figure 4.2.4.1.1: The diagram of the uALFAT and how it interfaces to other components. Reprinted with permission from GHI Electronics.

This device called the uALFAT [24] provided support for the FAT16 and FAT32 file systems which were excellent when dealing with the MP3 format. This device also allowed the user up to four simultaneous file accesses, had a fast start up and reconnect speed. The average file read from this device was on average about 60KByes/sec. With GHIElectronic's new firmware the uALFAT was also capable of interfacing with the new and improved SD cards like the SDHC cards. This Secure Digital High Capacity card allowed for greater storage capacity. Some other key specifications were that it had a Real Clock Time and a low power consumption of about 12mA. This would prove useful with all of the devices that the alarm clock had been using. Lastly, all of the input and output pins had a 5 volt tolerance which was in our range of 3.3V to 5V. Shown in Figure 4.2.4.1.2 is a sample image of the uALFAT device along with the pin schematic showing the different interfaces using uART, SPI, and I2C. The pricing was fairly expensive for this small component at $44.95 a piece from

GHIElectronics. Due to the cost of this device more ways of implementing the SD reader were looked into.

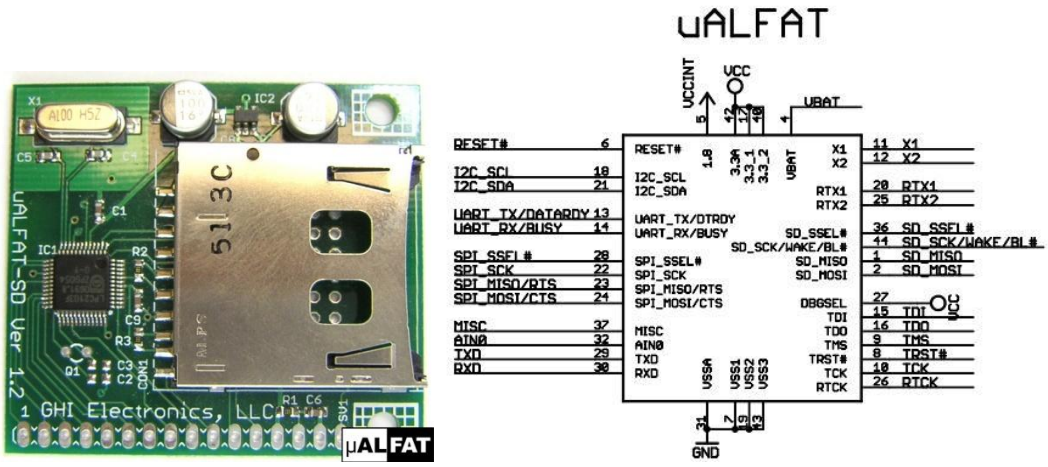

Figure 4.2.4.1.2: The uALFAT SD Card Reader as well as the pin assignments. Reprinted with permission from GHI Electronics.

Another type of SD Card Reader that was looked into was one that was found on Sparkfun electronics. This device called the Breakout Board [25] for SD/MMC devices was very similar to the uALFAT component that was researched above. There are small differences in this component such that the Breakout Board would only be using the SPI interface. After researching into which interface would suit best to work with the ATMega644P microcontroller the GuSu team found that the SPI interfacing worked best due to pin constraints on the microcontroller. The Breakout Board was also using considerably less pins than the uALFAT. This component also used a smaller voltage than the uALFAT at only 3.3 volts. Although this component seems like a great fit to work with the microcontroller, the power consumption was a 0.5A which was much greater than the 12mA used by the uALFAT. Once again, power consumption considerations were taken into effect when dealing with different components, the team made sure that there was enough current to power all of the devices in the alarm clock. Figure 4.2.4.1.3 shows the Breakout Board as well as the PCB schematic of this design. This component also allowed for data to be written and read from the SD card. The pricing of this module was only $17.95 and the team realized this would be a better buy due to the price as well as dealing with the amount of pins. The Breakout Board was easier to integrate to the MP3 decoder than the uALFAT.

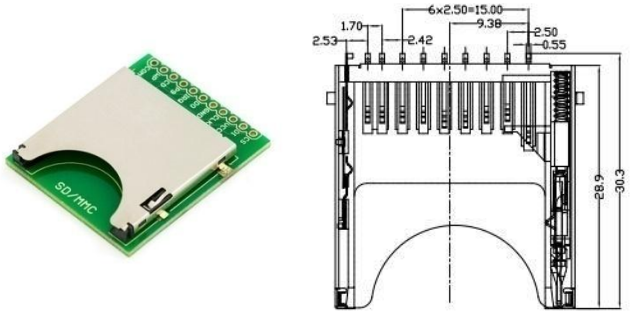

Figure 4.2.4.1.3: The Breakout Board SD Card Reader and its dimensions. Reprinted with permission from Sparkfun Electronics.

One more type of reader that was researched into was the USB SD Card Reader [26] from Sparkfun Electronics. This device seemed like a great choice for the GuSu prototype because it had support for all of the different types of SD formats such as SD, microSD, MMC, and compact flash. After realizing that the GuSu prototype needed some type of USB interface with the MP3 decoder the team thought that this proved to be a more challenging task that required extra work. Finding a USB interface that would interface easily with the STA013 MP3 decoder proved to add a lot of extra programming work on top of the large amount of programming already needed to be done. The team thought of another easy way to get around this by directly interfacing the USB SD Reader to the ATMega644P. Doing it this way proved useful in that the microcontroller could control the data being read from the SD card and would pass it to the MP3 decoder and then out the speaker. The team finally decided that this was the worst choice for the SD Card Reader because the USB interface to the microcontroller needed a way to be powered and this was adding to much implementation just for this one module of the GuSu alarm clock.

4.2.4.2 Implementation

After doing much testing with the SD Card reader it was decided to drop this component from the GuSu prototype. Reasons for abandoning this media reader are given in the testing section of the SD Card/USB Drive reader. The team went back and looked into the researched ways of reading media from a storage device. Although most of the research was done on SD Card readers, it was strongly felt that this device required an excessive amount of implementation and with time running short a more simple method of reading media was looked into. The team came across the VMusic 2 media module and it was decided to use this.

Firstly, what is the VMuisc 2 media module? The VMusic 2 module from FTDI Limited is an all inclusive media handler that has a USB host controller as well as the VS1003 audio decoder. Some of the specs behind this device are as follows. It contains the VNC1L-1A USB host controller which allows for the insertion of a USB flash drive that can store audio media. This controller is paired in line with the VS1003 audio decoder which was described in the previous section [27]. The

type of USB socket to connect with the flash media drive is type ‘A’. For audio output, the VMusic 2 has a stereo 3.5mm headphone jack that a cable can be connected to, this is where the speaker will be connected to. Seen in figure 4.2.4.2.1 is the schematic of the USB host controller. There are two different types of voltage regulators that are used in junction with the USB host controller. One of these is the MCP 1700T regulator. The other type is the TPS76428 which are a low-dropout voltage regulator which offers benefits of low noise, low-dropout voltage, and low-power operation. A special fact about these regulators is that they offer low quiescent current when you compare them to the standard regulators. More is discussed on the interaction with the ATmega644P microcontroller below.

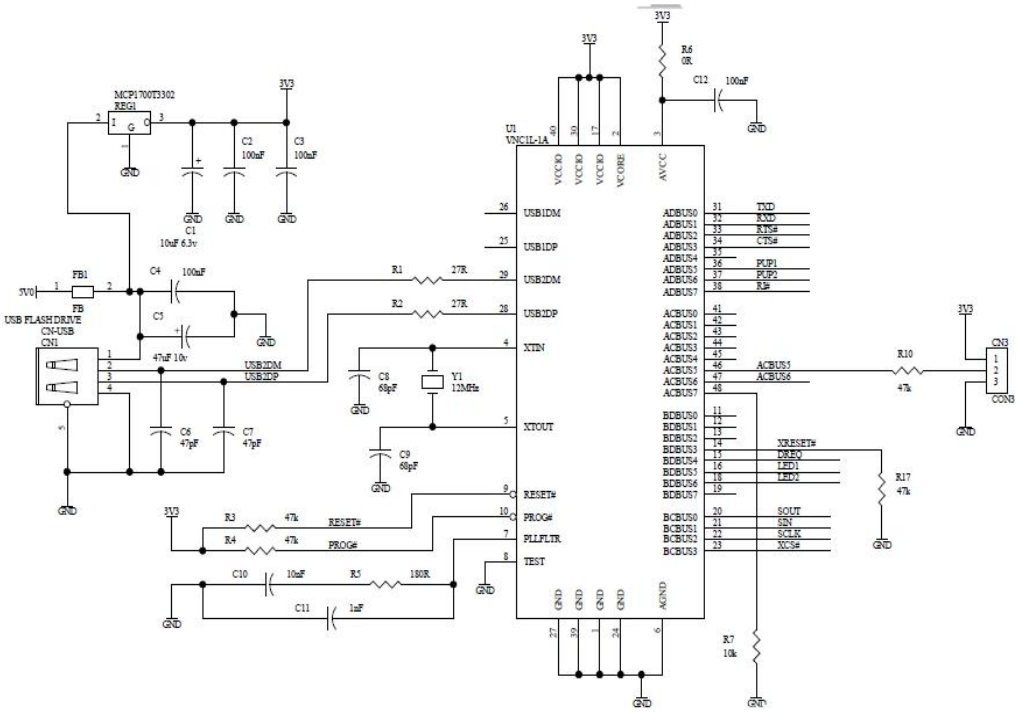

Figure 4.2.4.2.1: Schematic of the VNC1L-1A USB host controller. Reprinted with permission from FTDI LTD.

When dealing with the interaction of the VMuisc 2 and the microcontroller there are a few things that need to be taken into consideration. There are four connections that need to be made to the microcontroller. These four lines are the clock, serial data input and output, and the chip select. Digital pins three and four will be use on the ATmega644P for the digital input and output. The chip select line must be held high when entering the read cycle and is taken low for one clock period after reading is complete. All of the interfacing between this device and the microcontroller is through SPI but there is a uART connection that can be made for debugging and testing purposes. To power the device a standard 3.3V voltage line will be supplied by the power supply which runs through the printed circuit board along with a ground connection.

Figure 4.2.4.2.2 shows the VMusic 2 media module. Inside the plastic casing is the printed circuit board that controls the VS1003 and the USB host controller. On the front side of the module is the 3.5mm stereo headphone jack. To connect the speaker with this device a 3.5mm audio cable was used. One end will be connected to the headphone jack while the other end is stripped into the two lines where they are soldered to the speaker. On the other end of the module is the USB host controller where a USB flash drive can be inserted. A longer USB cable was ordered to use, the VMusic 2 module will be mounted inside the GuSu case along with the printed circuit board. A small hole is cut out of the back of the GuSu case where the USB extender cable will be mounted, this is where the user will insert their USB flash drive with audio media on it. There is also a LED status indicator that will let the user know when the device is powered on as well as when there is traffic that is read through the device. On the back of the module is where the lines to the microcontroller are placed. Using the VMusic 2 module would help the microcontroller deal with other processes in the GuSu system. The original implementation of using the SD Card reader would of hogged a lot of resources on the microcontroller.

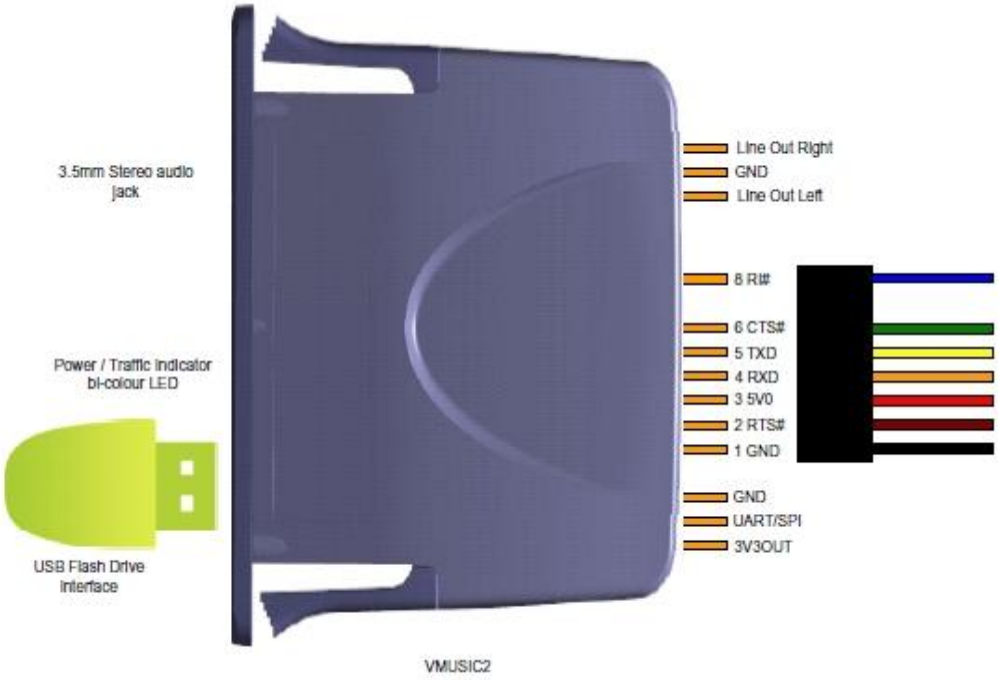

Figure 4.2.4.2.2: Shows the VMuisc 2 media module with the pin outs. Reprinted with permission from FTDI LTD [28].

After the connections were made to the microcontroller the team needed to format the USB flash drive so that the VMusic 2 would be able to recognize the partitioning format. The standard format that can be used is the FAT file structure allowing FAT16 or FAT32. The team needed to work on the software to control the device. The code would be implemented in C++ on the ATmega644P. The software was a small program that would allow the transfer of data through the

SPI interface. The microcontroller would request data from the VMusic 2 and send the output to the speakers as audio. This method of reading audio media was found to much simpler than the previous implementation the team had tried to accomplish. Having done the research prior to the original design was helpful in that it allowed the team to go back and look into other designs that would have worked with the GuSu prototype. Seen in the next section Testing are the steps that were taken to use the VMusic 2.

4.2.4.3 Testing

The original plan was to use the SD Card for storage of audio media files. The team spent about four weeks trying to get this device to work. It was wired to a breadboard on an ATmega168 for testing purposes; the plan was to connect it to the ATmega644P after it was found to be working. There were seven lines that were connected directly to the SD Card's pins. Resistors were used in series with some of the lines to the microcontroller. A 3.3V voltage line was supplied to power the SD Card. The team found many software libraries to control SD Cards and the Arduino microcontrollers. These libraries were looked into because writing the software to control this device would of required to much time when that time needed to be used focusing on other components. One of the problems was that a FAT file system would need to be coded in the software just to handle the FAT system on the SD Card. The main problem was that the software libraries were much too large to load onto the microcontroller, there wasn't enough memory. Even after testing various software to control the SD Card there was problems in getting the card to initialize. The team eventually ordered a SD Card socket where the SD Card could be inserted and wires were soldered to the printed circuit board to connect to the microcontroller but this proved to not be useful. After spending so much time trying to get this device to work the team eventually decided to drop this and look for another option. The team found a Wave Shield from Adafruit Industries that could work with the ATmega644P but the problem with this is that it was only able to play WAV files. This sound quality was not preferred; a more high-quality audio would be needed for the GuSu. Finally after looking back into the research and looking for a different option the VMusic 2 came across the teams' eyes. This option was ideal because the module had everything on it that was needed, a USB host controller and an audio decoder. Wiring to the microcontroller was very easy, much easier than the SD Card. A simple SPI script was written in C++ to control the VMusic 2. This was much simpler than the code that was required to control the SD Card. The pushbuttons on the GuSu can be used to control the play of the VMusic 2 with options such as starting or stopping the play and moving onto the next track. The team was very happy to have come across the VMusic 2 because time was running short and it was very simple to get implemented into the GuSu system.

5.0 User Interface

5.1 Motivation

In designing a user interface assumptions must be made and stuck to about the environment and user. An assumption that will affect most of the assumptions to follow is that the system will most likely be interacted with between dusk and dawn. For the environment there is a bedroom, likely low lit, and the GuSu device positioned within arm's reach from the bed. For the user it is assumed they are not fully awake, either due to being sleepy or having just been awoken by the system. It is also assumed that the user is a legal adult and has had interactions with basic consumer electronics and alarm clocks.

Keeping these assumptions in mind the more basic and default options given to the user should function as the user expects them to rather than a method that is easier to implement, or seems more sensible. Designs on paper can often seem perfectly intuitive and even innovative, but once realized can be clumsy or frustrating. In the design of the GuSu's overall user interface the combined graphical user interface and physical user interface are built around these ideals with the previously mentioned assumptions to create an interface that is simple to use, and straightforward as possible, hopefully so much so that almost anyone can use the GuSu system without reading an instruction manual. Before the UI is laid out in detail, figure 5.1.1 presents a block diagram of the UI's finalized abstract components.

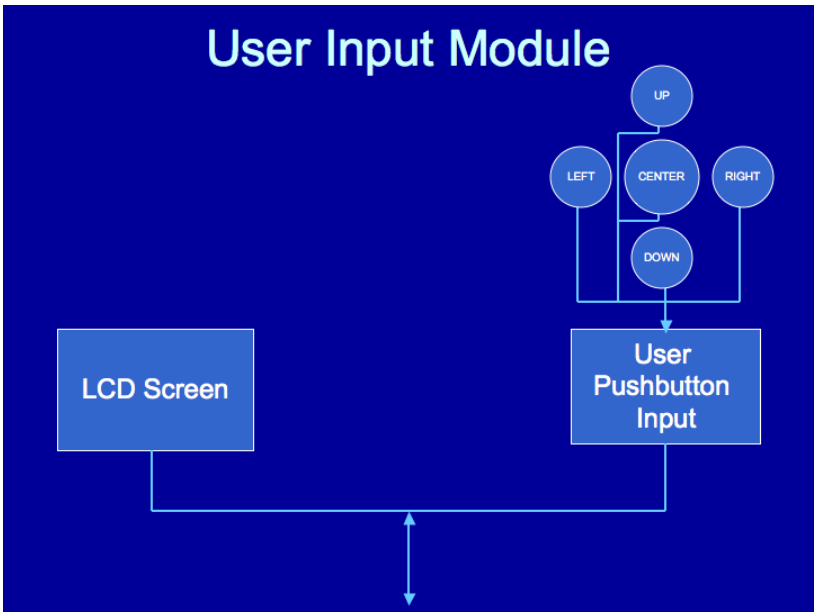

Figure 5.1.1 User Interface Block Diagram

5.2 Liquid Crystal Display

The alarm clock was also integrated with a LCD display for easy user access. LCD is short for Liquid Crystal Display and will be defined more in detail in section 5.2.1 of this document. The LCD display was integrated into the alarm clock through the microcontroller that was chosen in this design. The main purpose of having this display was so that the user would have an easy way to access the controls of the alarm clock. Some of the common features that were used on this display were a friendly user control panel as well as some buttons. The user control panel allows whoever is using the alarm clock to set their time, alarm time, and other features that will be discussed in detail. The buttons provide support to the user to change settings within the control panel. A discussion behind the history of LCD displays and the research that was put into the design will be examined in section 5.2.1 of the document.

5.2.1 Research

First off, a discussion of a brief history of the Liquid Crystal Display will be explained. Following this discussion will be important information about how this specific type of LCD display was chosen along with the research that went along with this decision.

Back in the late 1800s a chemist by the name of Friedrich Reinitzer had found liquid crystals in the cholesterol molecules of carrots. In the early 1900s there was various research done on these liquid crystals, they were finally classified into three types which were called nematics, smectics, and cholesterics. By the time of 1962 a member of the electronics company RCA named Richard Williams was the first to notice that the liquid crystals had electrical and optical properties by applying a certain voltage to them. In the following decades more work was done by researchers to harness the practical value of these crystals and how they could be used in electronics in modern society. In the early 1970s various patents were made in the USA as well as in Europe for creating the first twisted nematic LCD display [29]. Twisted nematic displays means that display contains liquid crystals that will twist and untwist at different angles which allow light to pass through them. Once this happened the dominos fell and work on the LCD displays increased dramatically with more and more patents being made in the following years. Figure 5.2.1.1 shows a common active-matrix LCD display. The liquid crystals are encased within two glass plates which have horizontal and vertical filters on either side of the glass. These are what create the horizontal and vertical sync lines on your LCD monitors or displays. To add color to the screen a color filter is added over the horizontal filter.

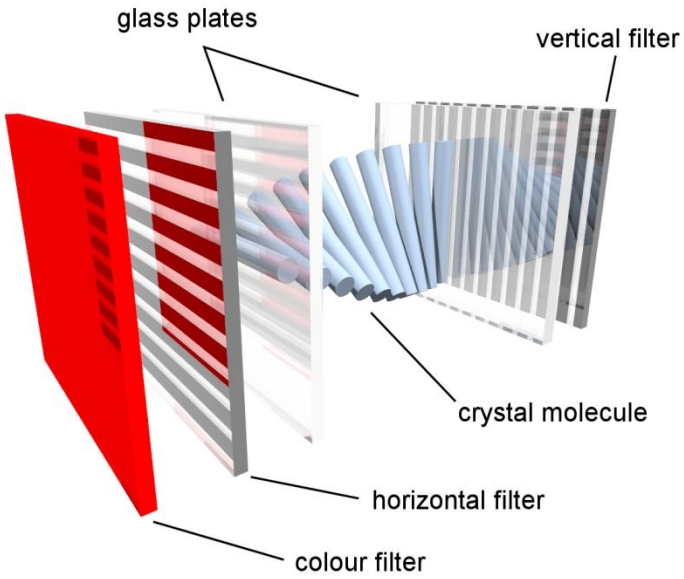

Figure 5.2.1.1: The common components of a LCD display and how it is assembled. Reprinted with permission under the General Public License.

By the time the new millennium had hit, LCD displays were being sold more than CRT displays. CRT is short for Cathode Ray Tube. These are usually the more bulky monitors or displays that are used with computers, CRT displays use a vacuum tube with three separate electron guns that shoot electrons to the screen. These electrons will emit from a screen that will show images on the display. By present day the LCD displays are the most popular form of imaging ranging from computer screens, laptop screens, and now more than ever TV screens.

Now, continuing onto the research methods that were used in choosing our specific LCD display. The team had researched various displays throughout the internet trying to find a LCD screen that would work with our microcontroller. Some issues in finding the perfect screen were backlighting, viewing angle, power consumption, and whether or not the display was capable of displaying characters. Detailed in the next paragraph is a comparison of two different LCD displays that were considered before choosing the appropriate one. Ultimately, the uOLED-160-G1 would prevail over the other displays that were looked into.
The first LCD display that was looked at was the 16x2 character LCD RS232-TTL. This display had many of the features that were required by our alarm clock module. This display required a +5V supply to power it while also having a high operating temperature range of up to 150 degrees Fahrenheit. To work with the specific microcontroller that was chosen the display had to have an SPI interface. SPI is short for Serial Peripheral Interface Bus, which is a synchronous serial data link that will operate in full duplex mode. Some advantages of the SPI interface over other interfaces such as I2C or SMBus are that it had a higher throughput as well as simple hardware interfacing. The only real disadvantage of

the SPI interface is that it required many more pins to run than the other interfaces. Pricing for this display was set at about $24.00 which wasn't bad for this type of display but was a bit pricey. After coming to the conclusion that the LCD RS232-TTL wasn't a suitable fit for the design because of limited capabilities of the LCD display and also the user friendliness of the hardware, the uOLED-160-G1 seemed to be the right choice for the design that was chosen.

The team decided that the just standalone character LCD displays wouldn't look aesthetic enough for what the GuSu design was trying to accomplish. The team decided that the OLED graphic displays would be a great visual aide for the alarm clock. Another display looked into from the same company that makes the uOLED-160-G1 was the uOLED-320XX-P1. Some of the specifications about this display were that it had a 240x320 pixel resolution with 256, 65k, or 262k true life colors on the AMOLED screen. The viewing angel was near perfect allowing the user to see the screen from about 180 degrees. The interface was SPI with the same pin configuration as the uOLED-160-G1 graphics display. The voltage supply could be run at 3.6V to 5.5V with the current being on average at 60mA which was pretty minimal for this type of display. Some extra features that were considered were the addition of the microSD memory card adapter and an audio amplifier with an 8 ohm speaker for audio playback. This display was great for the GuSu design but at a costly $149.95 this was definitely out of the price range for the GuSu team so this display was eventually ruled out.

Now, moving onto the uOLED-160-G1 graphics display and why it was chosen. This display was suited well for interfacing with the microcontroller having an uncomplicated and straight forward approach that connected it to the microcontroller. To understand the properties behind the OLED display a comparison was made between this display and the standard TFT display. OLED stands for Organic Light-Emitting Diode while TFT stands for Thin Film Transistor. Most LCD displays that are seen in stores and used with computers are TFT displays, but the OLED display has many advantages over the TFT. To understand why the OLED works the way it does a figure is provided to help the reader understand why it works. Organic material is placed between an anode and a cathode which is composed of electric conductive materials. By applying a voltage through the organic materials holes and electrons are injected to and from the anode and cathode in which luminescence will occur. To understand why the OLED is a better fit an understanding of TFT displays must be discussed. The TFT is a special kind of field effect transistor in which films of a specific type of semiconductor are used as both the active and dielectric layers sitting upon a substrate usually made of glass.

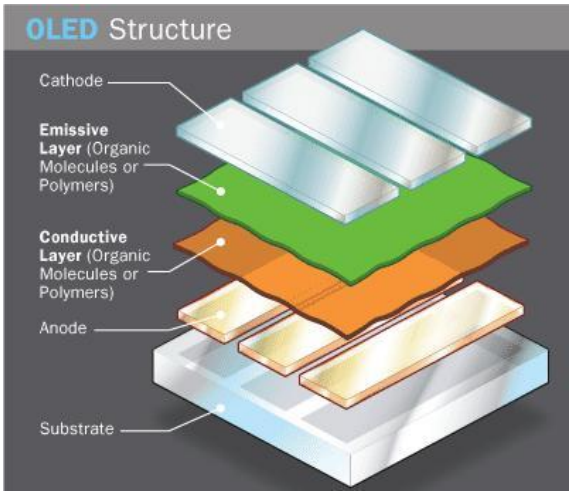

Figure 5.2.1.2: The hardware structure of an OLED display. Reprinted pending permission from HowStuffWorks.com.

Figure 5.2.1.2 shows the structure of an OLED display. This display was suited well for interfacing with the microcontroller having an uncomplicated and straight forward approach to connecting it to the microcontroller. There were many advantages that the OLED display had over the TFT and those will be discussed briefly. One of the major advantages was the high contrast ratio which could be up to 20 times the amount as a normal TFT display. The purpose of the contrast ratio is that it is a ratio of the luminance of the bright color being white to the darkest color being black. A higher contrast ratio provided a more detailed and fine picture than something with a low ratio. Another great benefit was the response time of the OLED screen. These displays can have an astonishing 50 microsecond response time while the normal TFT LCDs have somewhere in the range of 3000 to 30000 microseconds [30].

Power consumption is also considerably less than TFT because in the TFT displays a backlight must always be on to show images on the display while the OLED uses a black background to minimize power utilization. Knowing these facts about power consumption helped with the changing economies and the green movement. With the world's energy crisis at hand more and more people are turning to energy efficient products and the OLED provides that over the TFT displays.

Now, even with all of these advantages there are also disadvantages that come with them. The major one would be the price, since the OLED is more expensive to manufacture it is obvious that these displays cost more. The other drawback being the display's lifetime, the average lifetime of an OLED display is about 20000 hours whereas the TFT displays get about 50000 hours of use. Shown in figure 5.2.1.3 are sample pictures of the uOLED-160-G1. The left image shows the display sitting on top of the chip while the right image is the back of the OLED LCD display. The GOLDELOX-GFX graphics processor situated in the middle of

the chip, it is a black square. The graphics processing unit will be defined in further detail in section 5.2.3 of the document.

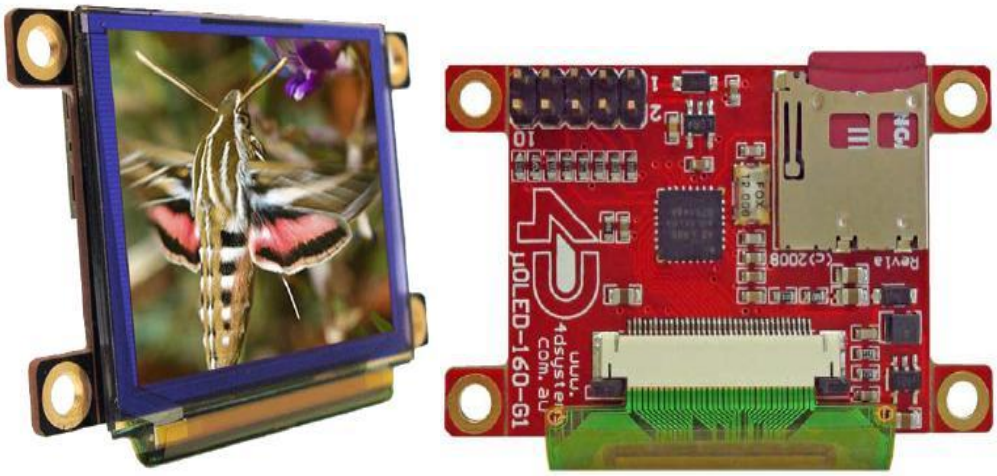

Figure 5.2.1.3: The µOLED-160-G1 LCD display as well as circuit board it is connected to. Reprinted with permission from 4D Systems.

5.2.2 Implementation

The alarm clock was also be integrated with a LCD display for easy user access. The LCD display was integrated into the alarm clock through the microcontroller that had been chosen in this design. The main purpose of having this display was so that the user would have an easy way to access the controls of the alarm clock. Some of the common features that were used on this display are a friendly user control panel as well as some buttons. The user control panel allows whoever is using the alarm clock to set their time, alarm time, and other features that will be discussed in detail. The buttons provide support to the user to change settings within the control panel. As seen in Figure 5.2.1.3 the SD card was inserted at the back and base of the LCD display. Powering the uOLED-160-G1 is the GOLDELOX-GFX graphics processor; this module will be discussed in further detail in section 5.2.3 of the document. Also shown in Figure 5.2.2.2 are the dimensions of the uOLED-160-G1 LCD display with a diagonal length of just about 1.7 inches. The cost of this display was set at around 100$ which was pretty pricey but not out of the teams budget.

Some of the specifications of the uOLED-160-G1 LCD display are as follows. The display has a native resolution of 160x128 pixels and 256/65K true color. This screen does not have any backlighting which is ideal for what this design is trying to accomplish; the imagery is near perfect having a 180 degree viewing angle. The uOLED-160-G1 uses a voltage supply from 3.6V to 6V. Although the standard that was used was a 5V compared to the 3.6V, which depended on whether or not the SD memory card was used along with the display. The micro SD memory card allows for images or animations to be displayed on the LCD, allowing a range of 64Mb to 2 GB memory cards. To connect this device to the microcontroller that was chosen a simple 5 pin interface is included on the LCD

display. These 5 pins account for the VCC, TX, RX, GND, and RESET connections and are connected to the microcontroller via SPI interface.

Interfacing of the uOLED-160-G1 to the microcontroller was pretty straight forward. The display was connected via the SPI interface and five pins were used on the LCD to power and connect this device. VCC was set in the range of 3.6V to 5V to power the display. The TX and RX which transmit and receive connections on the LCD display allowed the device to communicate with the microcontroller. These pin connections were used when sending signals and data to the display from the microcontroller. The microcontroller also has the ability to read information off the LCD. The software code that implemented this will be discussed in the Software section of the document; this includes the initial pseudo code. The last pins that were connected are the ground and reset. Reset was used to change the device back to the factory defaults.

This display fits snugly onto the GuSu prototype case. The uOLED-160-G1 is facing on the front side of the case and this is where all interaction between the GuSu prototype and the user occurs. Pushbuttons accompany the LCD display which allow for configuration changes. Seen in figure 5.2.2.1 is a sample of the connections that were made between the uOLED-160-G1 and a microcontroller using the 5V system.

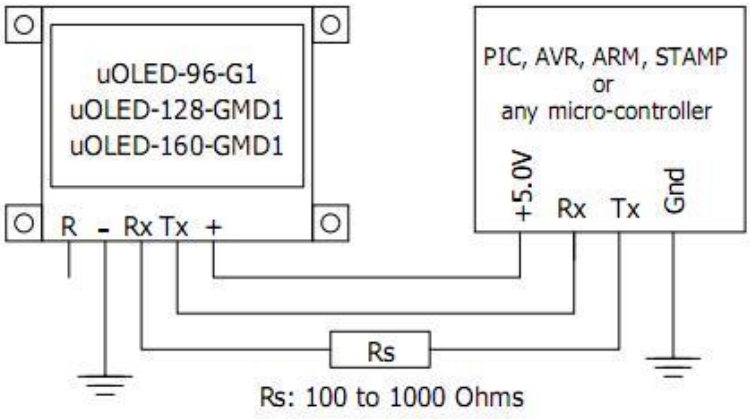

Figure 5.2.2.2: The interface between the uOLED-160-G1 and a microcontroller. Reprinted with permission from 4D Systems.

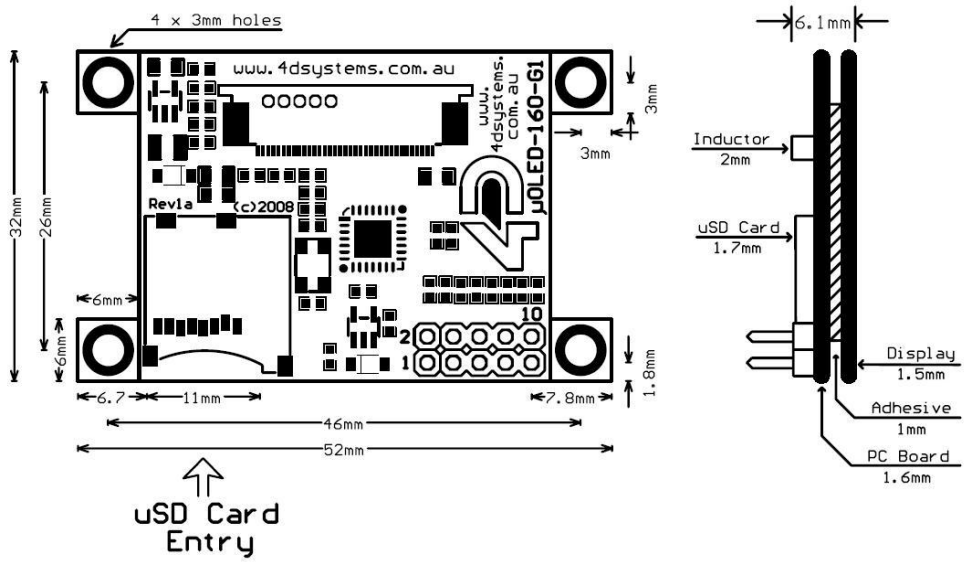

Figure 5.2.2.2: Layout of the uOLED-160-G1 LCD display and its dimensions. Reprinted with permission from 4D Systems.

5.2.3 LCD Driver Chip

In this section of the document the LCD driver chip will be explained in detail. This is the graphics processing chip that is located in the center of the LCD display chip. This particular chip is called the GOLDELOX-GFX graphics processor [30]. This type of processor will easily interface with many of the different types of TFT and OLED displays. The graphics processing unit allows an output of high-level graphics along with multiple I/O functions. All of these functions are controlled by E.V.E. which is short for Extensible Virtual Engine. This new type of virtual processor created by 4D Labs allows code that was implemented to work with the GOLDELOX-GFX processor to work on other 4D Labs processors. This is a major advantage to this new type of architecture because once you have implemented code to work on the GOLDELOX-GFX you will not need to change the code to work on other devices. 4D Labs has written software named the 4DGL Workshop as well as the Graphics Composer that will allow the software developers to easily code new features for the GOLDELOX-GFX and the OLED displays. There are several features that will interact with EVE such as SD memory card drivers, graphic functions, flash memory, and eventually an output via SPI interfacing. The GOLDELOX-GFX requires 4DGL which is a high level graphics language required by this processor. Some of the features that this graphics processor is capable of handling are color images, animations, and even video clips. Even though for this design's implementation these advanced features will probably not be used that much. Seen in figure 5.2.3.1 is the schematic of the GOLDELOX-GFX processor. Since this design focuses on the OLED display rather than the graphics driver the pin assignments of the processor will not be discussed in further detail. Shown in figure 5.2.3.2 are the absolute maximum ratings about the GOLDELOX-GFX processor.

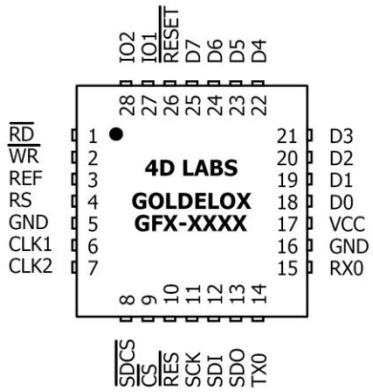

Figure 5.2.3.1: Package and pin assignments of the GOLDELOX-GFX graphics processor. Reprinted with permission from 4D Systems.

Absolute Maximum Ratings	
Operating ambient temperature	-40°C to +100°C
Storage temperature	-65°C +150°C
Voltage on any digital input pin with respect to GND	-0.3V to 6.0V
Voltage on analog pin with respect to GND	-0.3V to 6.0V
Voltage on VCC with respect to GND	-0.3V to 4.0V
Maximum current out of GND pin	300mA
Maximum current into VCC pin	250mA
Maximum output current sunk/sourced by IO1 or IO2 pin	4.0mA
Total power dissipation	1.0W

Figure 5.2.3.2: The absolute maximum ratings of the GOLDELOX-GFX graphics processor. Reprinted with permission from 4D Systems.

5.2.4 Testing

The OLED display was the first device to arrive in the mail and testing on it began immediately. The display came in tact when shipped and it was very easy to wire up to the microcontroller. A standard breadboard was used with a 5V voltage line supplied with ground. The TX and RX lines were connect through uART to the ATmega644P. The team didn't use the on board microSD card reader because there was no need for it. A small program was written in C++ in the Arduino development environment to communicate with this display. Simple test signals were written in this script to see if the display could output text characters which were successful. Now knowing that the display was working more work was being done on the GuSu menu system which is the main control to the system. All of the interaction would be done through the display and pushbuttons. Finally after the menu system was written in C++ which took weeks to complete the display would need to be mounted inside the case. There were four holes on the corners of the display that are screwed into the back of the front side of the case. The connection and power lines were then connected to the printed circuit board. After knowing that the power supply was working with the 12V wall wart the system was powered on and the display started in the SetMode which meant that the implementation of the OLED display was successful.

5.3 Physical User Interface

Since the PUI greatly influences the design and capabilities of the GUI, its overall architecture must be decided on first. Options vary from two pushbuttons to a full thirty-six button keypad, and these can be bought pre-labeled, or be positioned and labeled on the device. Building a custom button system however would require the user to do more learning in order to use the system and at times force them to look at the buttons when interacting with it. Furthermore it would create additional engineering hours for the design and implementation of such a button display, making this option the least desirable.

5.3.1 User's Expectation

In order to design a physical interface that the user will need little to no instructions for a variety of alarm clocks on the market were looked at. Rising in popularity are alarm clocks that can both charge and redirect audio from iPods. These devices make a good competitor model to the GuSu system as they tackle the challenge of allowing a user to have a variety of options, including personalized audio selection, for waking. The latest model in the iHome lineup, the iP9SR, has the features listed in figure 5.3.1.1 f33].

- Wake or sleep to iPhone, iPod®, AM/FM radio or buzzer
- Universal dock with inserts to fit docking iPod models
- Weekday/weekend alarm settings
- Programmable snooze times
- Charges iPhone or iPod while docked
- High-fidelity stereo drivers in specially designed Reson8® speaker chambers deliver astounding clarity, depth, and power
- Line-in jack
- Gradual Wake and Gradual Sleep increase/decrease Alarm/Sleep volume so as not to startle the user
- Full function remote control controls unit and iPhone/iPod menu functions
- Dual alarm with AM/FM presets
- Bass, treble, 3D and balance controls for best sound
- Extra-large, backlit custom LCD Display with dimmer
- DST switch for quick daylight-savings time adjustment
- Backlit buttons

Figure 5.3.1.1: List of features for an iHome

Most of these features work towards offering the user a wide selection of options while making control of the device straightforward. Widely recognizable symbols are used where ever possible to mark control buttons (such as the power, play/pause, and alarm 1/2 buttons), scroll wheels with a center buttons which mimic the iPod's control interface are used for volume and numerical incrementing and decrementing, and a large button that is as wide as the control area doubles as a snooze button and LCD back light dimmer. The GuSu alarm system will take advantage of the computing power of its micro controller to have

seven day programmable alarm times. In a similar fashion the iHome takes advantage of what is now cheaply available electronics to give the user weekday/weekend alarm timing, this also gives weight to the design assumption made for the GuSu system that more and more users have use of such a capability. College students especially have varying morning schedules that often fluctuate day to day and many times over a year.

An example of a product on the market which solves the other challenge the GuSu tackles, waking a user who needs a little more motivation than the alarm simply sounding, is the Flying Alarm Clock from Vat19.com. This alarm clock features a small plastic propeller that is launched at alarm time that the user must retrieve and replace on top of the clock to silence the alarm. For many this is ample extra action needed to awake and stay out of bed, however, there is nothing preventing the propeller from landing on the bed or within arm's reach of the bed, allowing the user to silence the alarm while remaining in bed. Disregarding this possibility, it is unlikely it will take much time to retrieve the propeller and this violates one of the key design requirements of the GuSu alarm system, the user must not be allowed to occupy the bed during the alarm time. The Flying Alarm Clock from Vat19.com also has a snooze switch and modes that do not utilize the propeller, violating another requirement of the GuSu system that the only way to silence the alarm in a timely fashion is to leave the bed [34].

Most of these products such as the iHome and iLuv have a simple backlit LCD screen, basic play/skip/stop controls for the attached mp3 device, and just enough buttons for adjusting clock and alarm times. The GuSu alarm system handles mp3 audio through the SD card slot and MP3 decoding module discussed in their sections of this document, but still requires a method for time setting. Most digital display alarm clocks use similar control methods as the iHome and iLuv involving holding down a button for either clock time or alarm time and tapping or holding a button for hours or minutes which increments the desired value. In table 5.3.1.2 various available pushbuttons and keypads are compared for price and function.

Item No.	Description	Supplier	Unit Price ($)
PSPST01	SPST off-on Red Pushbutton	[31]	0.45
PSPST10	SPST on-off Black Pushbutton	[31]	0.45
PRBLK	SPST Round off-on Black Pushbutton	[31]	0.65
SPBLK	SPST Square on-off Black Pushbutton	[31]	0.45
PLBLK	Black Large Pushbutton	[31]	0.45
KEYSWITCH01	Mini SPST Key Switch	[31]	4.90
KEYPADSM	12 Button Small Keypad Switch, 51mm Wide, 64mm High, 7mm thickness	[31]	2.20
KEYPAD4X4B	16 button keypad switch, 75mm wide, 80mm high, 17mm thickness	[31]	4.40
(SWP) 3W720-SS20	General instrument snap action pushbutton SPST, red lens, can be lighted, 5/16" mount, 1-1/16" long.	[32]	4.00
(SWP) SPM	2 pole 5 amp contact pushbutton switch, maintained contact	[32]	9.00
GH5008-ND	KEYPAD 12 KEY BLK FRONT PNL MNT	[33]	12.26
MGR1104-ND	KEYPAD 36 KEY W/LEGEND SEALED	[33]	75.10
MGR1501-ND	KEYPAD 12 KEY VANDAL RESISTANT	[33]	64.72
MGR1516-ND	KEYPAD INDUSTRIAL 4 KEY ARROW	[33]	30.86
GH5010-ND	KEYPAD 16 KEY BLK FRONT PNL MNT	[33]	13.66

Table 5.3.1.2: Table comparing basic options for pushbuttons and keypads

A full thirty-six button keyboard is unnecessary for this application, and given the assumptions about the user and environment, high end push buttons are also unnecessary. From the user's perspective the 4X3 or 4X4 matrix keypads would seem an easy choice. Setting the various time based settings would be simple, menus and non on/off options could be itemized and navigated quickly. However, the user would at times need to look away from the GUI to examine the keys to ensure proper input, and pay attention to what each button does as it changes with menu navigation. Using number input and having so many keys would also require invalid input handling, while controls for number incrementing would only require having loops for hours and minutes that go from 1 - 12 and 0 - 59 respectively.

For the GuSu alarm system the GUI should provide the user with detailed

information and allow them to interact and control the device with minimal action on their part. So the entire user interface will be built on and designed around a moderately sized graphical liquid crystal display and five pushbuttons oriented in an UP, DOWN, LEFT, RIGHT, CENTER orientation. While this will require more programming and testing during the design and implementation phase, it provides the user with the aforementioned easy interaction, spending more engineer hours rather than forcing the user to do more to use the system.

5.3.2 Key switch

As a deterrent to silencing of the alarm, the idea of using a key switch on the bottom of the GuSu unit for changing between RUN and SET mode was proposed. This would force the user to have the key nearby, turn the unit over or on its side, and insert the key to turn the alarm from RUN to SET. This would be easy to implement, and relatively effective since the key could not simply be left in the key-turn slot indefinitely. Unfortunately this not only gives the user a relatively quick way of silencing the alarm and returning to bed, but if the key is lost or damaged the user loses control of the GuSu system. Additionally having to keep track of the key and turn the unit over each time they wish to change modes would become a hassle after several uses. Therefore this idea is being left out of the design due to the above complications and negative aspects.

5.3.3 Physical User Interface Implementation

The area surrounding the push buttons is flat, allowing the user to find the buttons easily by brushing their fingers across the top surface of the GuSu unit. The CENTER pushbutton is slightly lower than other pushbuttons, making it easier for a user to orient their fingers. All other pushbuttons (UP, DOWN, LEFT, RIGHT) are the same height and oriented at ninety degree intervals around the CENTER pushbutton. LEFT and RIGHT are aligned along a line parallel to the front of the GuSu unit, while UP and DOWN are oriented on a perpendicular line to LEFT and RIGHT. Going clock wise the directional pushbuttons shall be wired in the following order; UP, RIGHT, DOWN, LEFT.

In the interest of ease of programming the GuSu system has been built using off-on pushbuttons, and is designed around the SPST round off-on black pushbuttons available from Sparkfun. These have a mounting diameter of 6mm and height of 7mm. Figure 5.3.2.1 is a stock photograph of the pushbutton followed by theoretical schematics of the pushbutton layout.

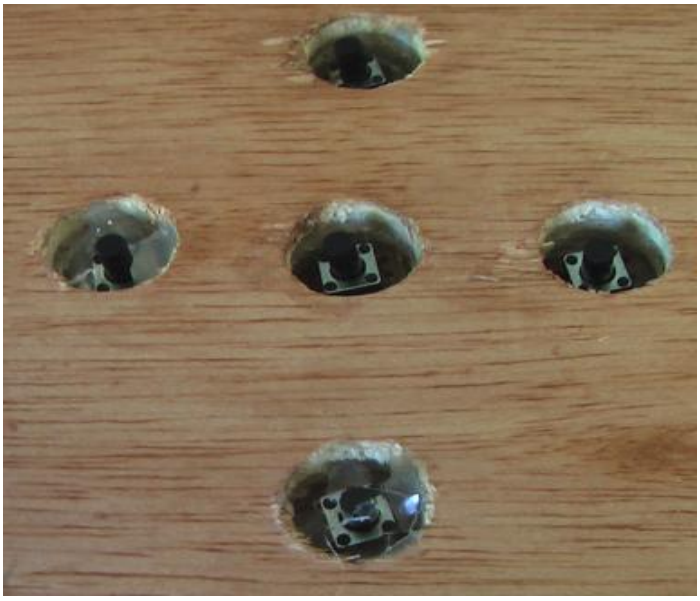

Figure 5.3.2.1 Pushbuttons mounted to final case.

5.3.4 Physical User Interface Testing

Code was included in the GuSuMAIN program for displaying through serial output what logical direction (UP, DOWN, LEFT, RIGHT, CENTER) was being interpreted from pushbutton signals to ensure that pin assignment and circuitry is correct for all five pushbuttons. It was noticed that at times several button presses would be registered, so code was added to handle debouncing, that is preventing the clock speed of the processor from registering more button presses than the user input. This occurs by comparing what the last level of the pushbutton digital input was with the last time a button press was encountered. Additional code was later added to setting menus to allow the user to hold UP and DOWN to continually increment or decrement values without having to press the buttons over and over.

5.4 Graphical User Interface

The graphical user interface is run by software downloaded to the on board micro controller. It is displayed to the user on the LCD screen that has been implemented, and controlled by the pushbuttons discussed earlier. For the five push buttons to be able to control everything necessary for daily operation the GUI will emulate a branch model for menu handling. That is, upon entering the SET mode the user is presented with a list of categories to set, and upon entering one of these menus is presented with a sub set within that menu, and enter a sub set of each of those options, and so forth. While this is not the quickest or simplest design, it is straightforward, can be easily navigated, and would only require at most two buttons for changing/setting various features, options, and values available as user preferences.

The branch menu model was chosen for its common implementation and intuitive use. It is used in many retail electronics such as camcorders, Texas Instruments calculators, iPods, and more. Branch menus also relieve the user of needing to pay much attention to the pushbuttons other than knowing that their fingers are placed correctly over them, allowing them to keep their focus on the screen once they have begun interacting with the device. Even if the user has no prior experience with branch menus they should be able to quickly figure out how to do anything they intend as far as choosing and adjusting settings for the GuSu system. Furthermore, as mentioned earlier, branch menus greatly reduce the amount of invalid input checking necessary, as it gives the programmer full control over deciding the entire range of possible input. The sections immediately following this discuss the abstract design of the graphical user interface and how the GUI and PUI interact.

The graphical display has two modes; RUN and SET. The names are self-explanatory; however figures 5.4.1 and 5.4.2 show an example layout and list of what is shown when the GuSu is in RUN mode respectively. Figures 5.4.3 and 5.4.4 present a hypothetical layout for a setting screen and a hierarchical list of the SET mode's branch menus.

Figure 5.4.1: Running GUI Display

- Current Time in large display format
- Upcoming Alarm Time
- List of chosen alarm actions
- Current alarm action being taken (if user detected)

Figure 5.4.2: Running Display Info List

Figure 5.4.3: Setting GUI Display

- Clock Set
    - Weekday
    - Hour
    - Minute
    - AM/PM
- Alarm Set
    - Weekday
    - Hour
    - Minute
    - AM/PM/Off
- Alarm Actions
    - MP3
        - Use?
        - Delay
        - Duration
        - Test
    - FM
        - Use?
        - Delay
        - Duration
        - Test
    - Soft Buzzer
        - Use?
        - Delay
        - Duration
        - Test
- Loud Buzzer
        - Use?

        - Delay
        - Duration
        - Test
- System
    - Behavior
        - Alarm Time Span
        - Weekend EZ Off
    - Conifgure
        - Calibrate
    - Wireless
    - Use?
    - Delay
    - Test

Figure 5.4.4: Tree Mapping of Setting Branch Menu

5.5 Complete User Interface

Here the interactions between PUI and GUI, and the constraints involved, are laid out in detail in figures 5.5.1 and 5.5.2.

- Hold CENTER/ENTER for 3 minutes to enter SET mode during alarm time, 3 seconds during non-alarm time
- Hold DOWN for 5 seconds to cause Zigbee keychain to beep, hold again for 3 seconds to silence
- Hold UP for 5 seconds during non-alarm time to enter PLAY for MP3 or FM
- LEFT/RIGHT tune or skip songs in PLAY mode
- PLAY mode is overridden during ALARM time

Figure 5.5.1: Running Mode Controls

- Pressing UP or DOWN will move the menu selection up and down respectively.
- Pressing RIGHT will enter the selected setting/option/menu or do nothing if the user is already inside a value setting branch.
- Pressing LEFT will move back up out of a branch, do nothing if the user is at the top menu level, or exit a value setting branch without saving.
- Pressing CENTER/ENTER will enter a branch or save and exit a value setting branch.

Figure 5.5.2: Set Mode Controls

5.5.1 Complete User Interface Testing

Once both basic pushbutton testing and display testing were completed, both were integrated into the system and graphical user interface code was implemented and all menus and options were tested using pushbutton controls. This ensured that all looping and alternating values, such as minutes, AM/PM/OFF, etc. were working correctly. Certain menu labels were renamed in order to fit on screen, and eventually all display items were passed as strings or

character arrays. Originally the OLED software library handled some value conversion, however this resulted in some visual artifacts during menu use. Once all items were changed to be passed as strings of a set length, all artifacts disappeared and menu fixes were streamlined.

6.0 Sensor System

6.0.1 Motivation

The Get Up Stay Up alarm clock system requires a method of "knowing" when someone is in bed. So in an abstract way the sensor system receives the question of "is there a human occupant in the bed?" and transmits a Boolean answer back to the system for it to decide what to do next. This can be accomplished in a variety of ways, including weight sensing, distance, and infrared. The system ideally will be able to tell that only one person has left the bed if there are multiple occupants, preventing conflicts if multiple users have different waking times. At the absolute bare minimum the system should not give false positives for small pets, backpacks, purses, luggage, etc. The sensor system should also be secure in that it cannot be "fooled" in any easy way that an occupant has left the bed. The sensor system should also avoid being fragile if possible, given that sleeping habits vary widely among people and sudden movements or sleep walking should not result in damage to the system or present the potential for personal injury to the user. Lastly the sensor system shall be as uncomplicated as possible so as to be conducive towards ease of installation and reconfiguration by the end user.

6.0.2 Assumptions

In the design and implementation of the sensor system the following assumptions are made. The user has a bed with at least one side against a wall, the bed consists of a mattress on either a box spring or flat bed frame, and the bed is within arm's reach of the GuSu alarm device. The mattress total weight including possible memory foam layer and sheets and pillows is less than 100 pounds. Data was collected on the beds of the four team members and roommates to create a definite picture of the average college student’s sleeping setup. This data consisted of bed height, bed length, bed width, and the distance from the edge of the bed facing the subject’s current alarm to the alarm itself. The data gathered is shown in the table 6.0.2.1, with the last row containing averaged values for reference.

Surveyed	Bed Height	Bed Length	Bed Width	Distance to current alarm
P B	61"	80"	43"	58"
J R	32"	80"	75"	19"
A L	25"	80"	52"	14"
M O	24"	78"	64"	14"
J S	38”	78”	54”	7”
B N	27”	80”	66”	6”
D D	20”	80”	53”	10”
Average	32”	79”	58”	18”

Table 6.0.2.1: Collected data on bed sizes and alarm distances

6.1 Research

6.1.1 Weight Sensing

For sensing the weight of a bed occupant, options include load cells, force sensors, and FlexiForce. Load cells usually work by deformation to change electrical signals and are commonly used in structural sensing [3]. Force sensors are thin plates used for measuring surface pressure and displacement [3]. FlexiForce sensors are very thin circular force sensitive devices that produce lower resistance as the force applied increases [36].

6.1.1.1 Load Cells

Load cells could be placed beneath a mattress and can be purchased in sensitivity ranges beyond 5000 lb loads. This wide range of sensitivity makes measuring exactly how much weight has been added or removed from the sleeping area very feasible. Three viable form factors of load cells are pancake, load button, and donut types. Most load cells are cylindrical with a center pressure sensitive apparatus that changes the signal output as force is applied. Sensor thicknesses range from 0.25 inches to almost 2 inches, thus depending on the type of mattress, a solid piece of material with the same width and length as the mattress would need to be placed over the sensors and the mattress on top in order to get a proper reading of the total weight on the mattress. While the pancake and load button sensors might shift about, donut form sensors could have a small rod mounted to the bottom of this board that keeps the donut sensors in place as shown in figure 6.1.1.1.1.

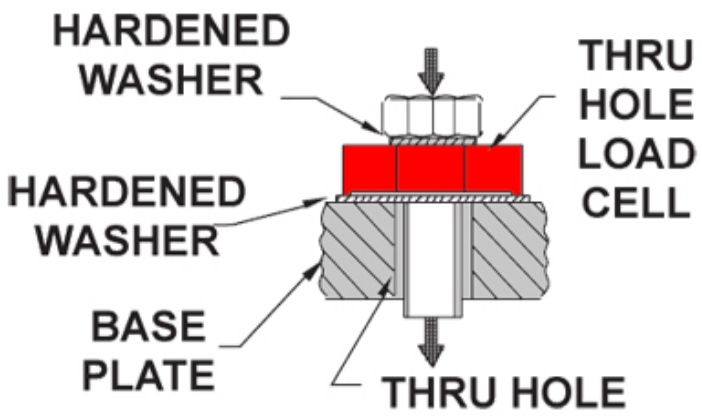

Figure 6.1.1.1.1 Schematic of a mounted Donut Load Cell
Reprinted with permission from Futek Advanced Sensor Technology Inc.

However, assuming that the user has space to spare for the sensors and the slat is hazardous, and adds unwanted complexity to installation of the GuSu system for the user. In addition it would require study on the effects adding such a layer between the mattress and bed frame or box spring would have on user comfort. Given that sensors available from FUTEK are designed for industrial OEM applications and use CC standard connection methods they would be difficult to integrate with the GuSu system.

6.1.1.2 Force Sensors

Also available from FUTEK are force sensors, available in weight sensitivity ranges from 1 ounce up to 40 pounds. These sensors are less than 0.1 of an inch thick (ranging from 0.025 - 0.05 in) making them exempt from most of the complications involved with load cells, and can be directly wired as a variable resistor. However, their sensitivity range presents a similar but new problem. Given that most bedding weighs near 40 pounds if not more the ability to measure changes in load is unattainable, and this is assuming any force sensors placed aren't already reading maximum load before any occupants have entered the bed. If the user did in fact own a memory foam layer or their particular mattress came with a detachable memory foam layer, force sensors could be used, but still would not be able to inform the GuSu system of exactly how much weight had been added or removed from the bed. Given that our environmental assumption does not include a memory foam layer, and that luggage and small pets could result in a false positive, force sensors are therefore not feasible components for this application. Figure 6.1.1.2.1 displays an example force sensor in order to demonstrate how thin most of available devices are [39].

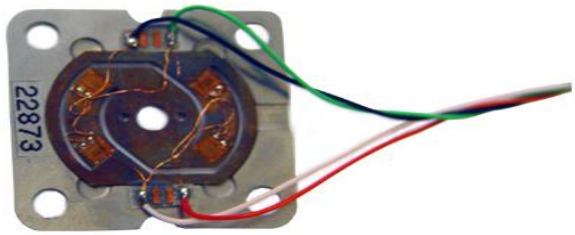

Figure 6.1.1.2.1 Example Force Sensor
Reprinted with permission from Futek Advanced Sensor Technology Inc.

6.1.1.3 FlexiForce

FlexiForce sensors, shown in figure 6.1.1.3.1, can be ordered for custom weight ranges, and come standard up to 100 lb sensitivity [37]. A convenient property of FlexiForce sensors is their sensitivity range can be tuned based on drive voltage and the feedback resistor connected in the circuit. This allows a maximum of 1000 pounds to be measured, once again making detecting different users and preventing false positives feasible. These devices also come in a thickness of approximately 0.005", and as the name implies are very flexible, reducing conditions for installation to a matter of positioning. FlexiForce sensors are also rated to handle forces up to 10,000 psi, removing any worry of damage throughout normal use.

Figure 6.1.1.3.1 FlexiForce IMAGE
Reprinted with permission from Tekscan Inc.

The arrangement and number of sensors needed depends on the sensitivity range of the FlexiForce strip. With the assumption that the user's total bed weight above the sensors is under 100 pounds, and assuming FlexiForce strips rated for 100 pound maximum force, simply detecting in several locations a maximum load would be sufficient for proper sensing of an occupant. However, this would make it near impossible to distinguish between two occupants, and

how many have left the bed. If custom FlexiForce strips are ordered the system could be programmed and calibrated to not only detect that a user's weight has been added or removed from the bed, but also could be programmed by the user for the approximate weight of any possible occupant if their individual weights differ significantly, and in turn when each needs to be awoken. This design is safe from mistakes involving most luggage and pets, and could avoid problems with couples or shared beds.

6.1.1.4 Conclusion

On the down side in order to use weight sensors the user would be responsible for the placement and calibration of the sensors. In order to silence the alarm the user could remove the sensors from under the bed when the alarm sounds and go back to sleep, defeating the key design element of the user having no easy way to silence the alarm, with the exception of leaving the bed entirely. Another problem is the added cost and the complications of if the user has a waterbed, or some non-standard bed frame, such as a bed over desk fixture, bunk bed, air mattress, etc. While most of these possibilities are not included in the assumptions made for the user environment, they are factors that limit the distribution of the GuSu system. Below table 6.1.1.4.1 compares sample products of the various pressure and weight sensing devices mentioned.

Type	Thickness (in.)	Load Range Available	Pricing ($)	Custom Order Available	Supplier
Load Cell	0.25 - 2.0	0-1000000 lb	500.00-2000.00+	No	[38]
Force Sensor	<0.1	0-40 lb	90.00-300.00	No	[38]
FlexiForce	<0.1	0-100 lb	25.00-117.00	Yes: max 1000lb	[36][37]

Table 6.1.1.4.1: Comparison of basic force/weight sensors

6.1.2 Distance Sensing

Another method of detecting an occupant in the sleeping area is to detect a change in range between some chosen point and the top of the bed. One or more sensors could be mounted over the bed in order to detect the distance to the highest point of the bed. With a twin size mattress one sensor should suffice, however double or king size beds are wide enough that an occupant could be missed. The most common methods of range detection include infrared and ultrasonic based sensor systems for finding the range to an object. Both IR and ultrasonic would be hard to use with multiple sensors positioned so close together. Therefore to use either the system would be constrained to using only one sensor, unless one of each kind was used. However, this would still not solve the problem of ensuring the entire bedding area is checked for a human

sized displacement, and with so few detectors the system could be fooled by pets and personal items. Given a user's tendency to move during sleep, the lack of full coverage of the sleeping area, and the complications with implementation of distance sensing this method of user detection is unsuitable for this application. Table 6.1.2.1 shows two distance measuring sensors available from Futurlec and Parallax.

Name	Specifications	Supplier	Price ($)
Sharp® Distance Measuring Sensor	Range: 100-550cm Output: 4.5-5.5V Supply: 0.5-3.0V L:60mm W: 37mm H: 20mm	http://www.futurlec.com	19.90
PING))) Ultrasonic Sensor	2cm-300cm Output: Variable width pulse Input: 4.5-6V L: 46mm W: 22mm H: 16mm	http://www.parallax.com	29.99

Table 6.1.2.1: Table comparing available distance sensors

6.1.3 Infrared

Infrared sensing has often been applied to motion and human body detection in the form of security systems and door operation. Implementation of infrared sensing falls under two main categories, emissive and passive. Emissive involves a unit radiating infrared over an area and detecting the reflections, usually in an effort to record or view a dark environment without being forced to light up an area in a way that a human eye can detect. Passive infrared sensor systems merely react to infrared radiation that passes over the sensitive elements and produces an electrical reading. In this case the system only needs to "know" if a user is present, and given that humans emit large amounts of infrared black body radiation, an emissive infrared unit is unnecessary.

For focusing or widening the effective angle of an infrared sensor, lenses can be made or attached to gather or deflect incoming radiation. Since the objective of the GuSu alarm system is merely forcing the user to rise from bed and not expel them from the sleeping area completely, a lens will most likely be needed depending on the distance and positioning of the sensor in relation to the bed. Experimentation with different distances, positions, and lenses will be needed during the second session of senior design to decide on an optimum setup, however examples of implemented infrared sensors and component specifications allow for a set of educated guesses as a starting point.

Passive infrared sensors present a good middle ground as far as meeting base requirements and optimum performance requirements. An infrared sensor or array can easily inform the GuSu system that the bed is occupied by a human

and will not produce false positives due to luggage and other personal items being set on the bed. However, small pets and occupants besides the user will produce a positive signal. It is possible with adjustments to the analog to digital conversion to adjust the sensitivity of the sensor, that is setting a certain threshold for it within the converter, but most likely anybody giving off heat will activate the alarm. Perhaps this is not a bad thing as it may optionally be used to deter pets from entering the bed. An infrared sensor is also hard to "trick" short of lifting a plate of glass above the user or a small piece blocking the sensor's view. Furthermore with the sensor mounted to the wall or ceiling this won't be an easy task, and yanking on the wires connecting the sensor would damage the wall, ceiling, or the GuSu unit itself.

In the interest of user preference, Fresnel lenses could be included with focusing lenses giving the user a choice between being forced to rise from bed and being forced to leave the room entirely to silence the alarm. For this application our "default" setup will be made assuming the use only wishes to be awoken and made to leave their sleeping area. A small stand could be constructed or a camera tripod included that allows the user to position the infrared sensor on any flat surface and aim it at their bed if they prefer this over drywall mounting and have such a position available.

6.1.3.1 Infrared Lenses

Most lenses used with infrared such as Fresnel lenses are made to gather and focus so as to allow a small sensor to cover a wide area, especially in respect to security monitoring. In this case the sensor is meant to cover a specific area no larger than the size of a bed and not too small that it would allow a sleeping or waking occupant to be undetected on the bed. Glass housing would both eliminate infrared radiation from sources outside of the area of interest and make the sensor less noticeable, however using such would make production expensive and the sensor unit fragile and possibly dangerous, violating basic requirements of the system. Infrared sensors, components, lenses, and pre-made circuits for infrared motion sensing are available from many companies and in differing configurations. For quick reference during final design and build table 6.1.3.1.1 was created in case parts need to be changed.

Part No.	Description	Specifications	Price ($)	Supplier
PIR_D203B	Infrared Radial Sensor	Supply: 3-15V 120º vertical 110º horizontal	1.90	[31]
PIR_D203S	Directional Infrared Radial Sensor	Supply: 3-15V 125º vertical 42º horizontal	1.90	[31]
FRESNEL	Fresnel Lens	Used with above sensors	0.35	[31]
PIR_MODULE	PIR Sensor Module	Supply: 5-20V Delay: 5s-18m Motion Detection TTL output	6.90	[31]
PIR_MODULE_B	Compact PIR Sensor Module	Supply: 5-20V Delay: 5s-18m Motion Detection TTL output	7.40	[31]
CS9803	Infrared Induction Control IC	Supply: 4.5-5.5V CDS input Noise immunity	0.90	[31]
SEN-08630	PIR Motion Sensor	Supply: 5-12V Delay: 1-2s 0.1" pitch female connector	9.95	[39]
DEV-08645	Motion Detection Module	Low power Status LEDs on board JTAG connector Supports: Olimex, TI SBW	23.95	[39]
55-28027	Parallax PIR sensor module	Supply: 3.3-5V Parallax connectivity	9.95	[40]
AMN13111	Panasonic Electric Works Infrared Sensor	Supply: 3-6V Digital Output Settings: (standard, slight motion, spot)	33.44	[41]
AMN2111	Panasonic Electric Works Infrared Sensor	Supply: 4.5-5.5V Analog/Digital Output Settings: (standard, slight motion, spot)	12.62	[41]

Table 6.1.3.1.1: Table comparing available PIR sensors and pre-made modules

6.2 Implementation

Based on the related research, assumptions made with respect to the project, and time constraints, an infrared sensor with a focusing lens wired to the GuSu unit is the best candidate for implementing a sensor system that satisfies our requirements. Implementation of weight sensors coupled with IR would be the optimum system for the reasons stated in the research section, and using both of

these systems together eliminates most of their respective cons. In the end pressure/weight sensing was implemented due to difficulties implementing infrared. It was found through testing that a user could escape a common passive infrared sensor using thick blankets or clothes. Attempts were made to use thermal infrared sensors but reliable readings could not be achieved. The team settled on a pulsor stress sensor from Sure Action Inc., these are resistive flexing sensors whose resistance changes as they are bent by tiny amounts. Mounting a pulsor to a bed frame prevents the user from being able to hide from the sensor as their weight will always cause a flexing in the frame of the bed no matter where they lay. The sensor itself is wired in parallel with a 1k Ohm resistor in order to create a voltage divider, and the voltage level across the sensor and resistor is read by an analog pin on the microcontroller. The sensor itself is epoxied to any flat surface that will bend when the user enters the bedding area. Most likely this would be a base board crossing the center of mattress, however on certain frames a side panel might be more appropriate. A calibration option is included in the GuSu system's menus allowing the user to save the readings for when they are in and out of bed. During alarm time the readings from the sensor are taken and averaged before being compared with the empty readings stored earlier. If a certain threshold is passed, which is calculated by taking half the difference between the empty and full readings stored earlier, the GuSu system will assume the bed is occupied and take action accordingly. Figure 6.2.1 depicts the original plan for infrared sensing, while 6.2.2 shows the actual pulsor sensor mounted to the wood for testing and demonstation.

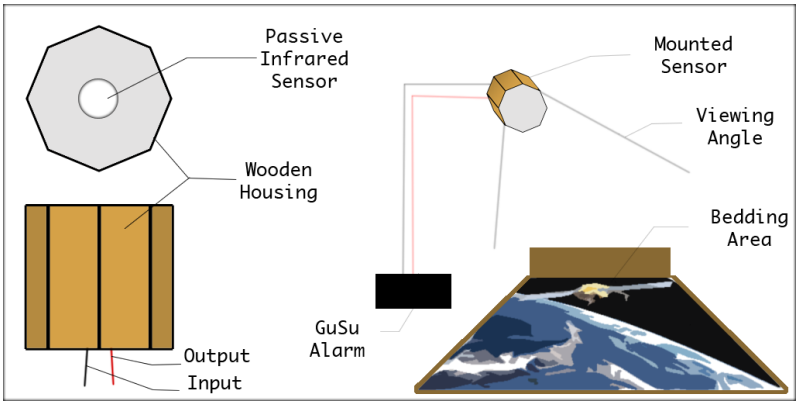

Figure 6.2.1: PIR Sensor Mounted Schematic

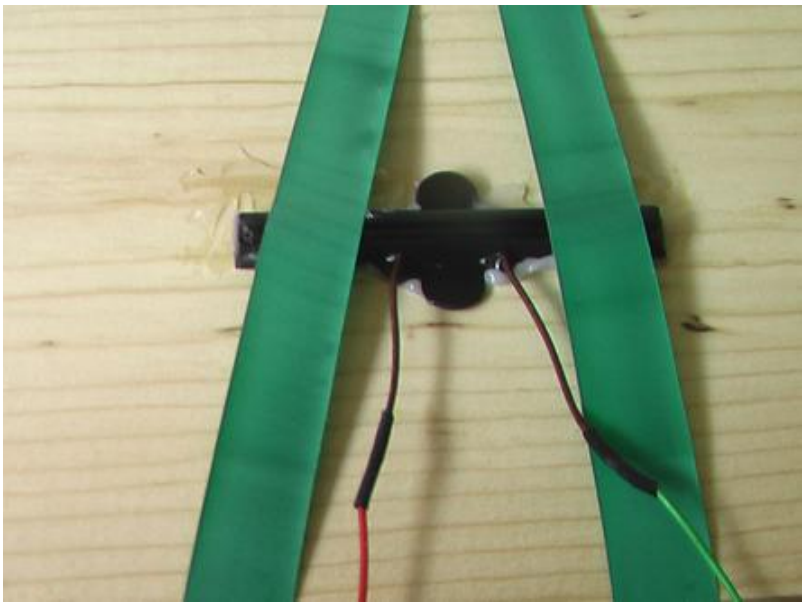

Figure 6.2.2: Pulsor mounted to 1x4x4

6.3 Sensor System Testing

The pulsor sensor was wired to an analog pin in parallel with a 1k Ohm resistor and the reading was directly output to the serial monitor included with the Arduino IDE. Values were read as one of the team members would sit on a chair while another teammate held the sensor to the bottom of the chair. Significant changes in the readings assured the team that the sensor would work once fully implemented and so the sensor was epoxied to a 1X4X4 piece of wood. Twelve foot wires were run from the sensor to the unit and tested. However, something between the epoxying of the sensor and the wiring destroyed the pulsor and readings of infinite resistance were being read. The pulsor was removed from the wood and the spare sensor was epoxied to the other side. This time correct readings were received, and with slight code changes and calibration the sensor worked as expected. One of the teammates would sit on the wood, resulting in alarm actions being taken by the GuSu system, and once the person stood up from the wood all actions would stop. Upon weight being re-applied to the wood alarm actions would begin again.

7.0 Radio Frequency Transmission

7.0.1 Design and Requirements

The project requires secure, low power, a range of 100 meters, and two-way wireless communications. Security is a major requirement in order to prevent false triggers which could potentially lead to fires if the user chose to plug a coffee machine or other heating device into the appliance module. The team researched many different topologies and specifications but three wireless specifications met the minimum requirements of the project. There are many

other protocols and available for use but the team felt the three listed provided the met the standards required in the alarm clock. ZigBee and Bluetooth are both IEEE ratified specifications that are readily available and Z-Wave is proprietary but is currently used extensively for home automation applications. All three topologies form a wireless personal area network (Table 7.0.1.1).

By using a standard transmitter/receiver the need to design and test radio transmission for the transceivers is eliminated as the radios already comply with FCC. Table 1 contrasts the three different topologies based on our needs.

	Security	Power	Topology	Range
Bluetooth (802.15.1)	SAFER+ block Cipher	100mW (class 1)	Star, point-to-point	~100m
ZigBee (802.15.4)	128 bit AES	1mW	Star, mesh, point-to-point	~100m
Z-Wave (proprietary)	None (required at application level)	1mW	Star, mesh, point-to-point	~30m

Table 7.0.1.1: Wireless Technologies Comparison

7.0.2 Research

7.0.2.1 Bluetooth

Bluetooth is designed as a wireless replacement for wired RS-232 communication. It is a low power communication protocol which maintains three classes (Table 7.0.2.1.1) for radio transmission. Class 1 devices met our design requirements for secure wireless communication but failed based on the power requirements for the device. The data is transmitted using FHSS (frequency hopping spread spectrum) chopping the data and transmitting it on up to 79 different frequencies. The data is transmitted over the ISM (scientific and medical) band running at 2.4 GHz short range frequency band.

Class	Maximum Permitted Power mW (dBm)	Range (Approximate)
Class 1	100 mW (20 dBm)	~100 meters
Class 2	2.5 mW (4 dBm)	~10 meters
Class 3	1 mW (0 dBm)	~1 meter

Table 7.0.2.1.: Bluetooth Classes

Bluetooth supports a number of protocols including but not limited to dial up networking profile (DUN), Personal Area Networking profile (PAN), and the service port profile (SPP). The profiles of interest to the group include the PAN profile and the SPP profile. The PAN profile describes how two or more Bluetooth enabled devices can form an ad-hoc network and how the same mechanism can be used to access a remote network through a network access point. Using this protocol the alarm clock would function as the

server/coordinator and the appliance module as the end device. The Bluetooth protocol supports up to seven clients at a time. This would allow a small expansion to other devices connected to the alarm clock such as a light/lamp switch or using received signal strength indication (RSSI) a Bluetooth transceiver could be used to detect when a device such as a key chain has left the network range. This could be used to develop an algorithm to determine optimal wake up time to allow the end user to sleep until it was necessary to get out of bed (based on average times of departures). The other profile which could be potentially used is the SPP profile. This profile creates a one-to-one interface between the server and client using virtual serial ports. This would be the optimal communication protocol for our devices as the microcontrollers supports this profile and the Bluetooth devices would emulate the serial transmission between devices. The drawback to Bluetooth devices is the expense in the development and the limited availability of development kits. Sparkfun, an online retailer, provides a Bluetooth development kit. One in particular meets the SPP specifications. The Roving Networks Bluetooth module supports the SPP profile and is available in a DIP. The device does require an RS-232 TTL converter to communicate with the microcontroller. The device is expensive costing $59.95 and the project would require a minimum of two devices for the current implementation.

7.0.2.2 Z-Wave

Z-Wave is very similar to the ZigBee specification in that it allows mesh networking between devices and was designed for home automation and sensor networks. It evolved from the 802.15.4 consortium and is now adopted by more than 200 companies [45]. Zensys, the parent company of Z-Wave, uses the same PHY and MAC layers as ZigBee but implements a proprietary Application/Framework layer. Z-Wave operates in the sub- gigahertz range and is used for low data rate transmission. The low data rate is used for on/off commands for devices such as light switches and remote controls. Metadata can also be transmitted. Since the operating frequency at the 900 MHz frequency range is not prone to the commonly used 2.4 GHz ISM frequency range employed in devices such as Bluetooth, Wi-Fi, and cordless phones. Microwaves also operate in the 2.4 GHz frequency range and can interfere with devices that use that spectrum. If the alarm clock were to be distributed internationally the 900 MHz range would need to be modified as this is not a common open frequency available in other countries as is the 2.4 GHz range. Z-Wave is designed specifically for home automation and security. This makes the protocol an optimal choice for the alarm clock project. The coffee machine, the light switch, and the alarm clock could all be monitored and maintained and controlled with a more robust PC application. The clock could be set over the wireless connection; the appliance module could be controlled over the internet or with the clock. There are already a large number of end devices available made with Z-Wave technology and the market is well established. There is a single problem with implementing the alarm clock system with Z-Wave. The high development costs. The software development kits alone cost $3500 which does

not include any hardware. A company called Control Think offers both a hardware and software development kit for only $100, but development would depend on a company with an uncertain future. Because of the high development costs for software and hardware, Z-Wave was eliminated as an option for our product.

7.0.2.3 ZigBee

ZigBee is a standardized protocol for wireless personal area networking or WPAN developed for sensor and automation applications. There are three different types of ZigBee devices: the ZigBee network coordinator, the ZigBee router, and the ZigBee end device. The coordinator links act as the master controller and links router and end devices. They form a tree network which can be seen in figure 7.0.2.3.1. The mesh uses a self healing star topology (figure 7.0.2.3.2) that allows the short range multi-hopping communication between nodes.

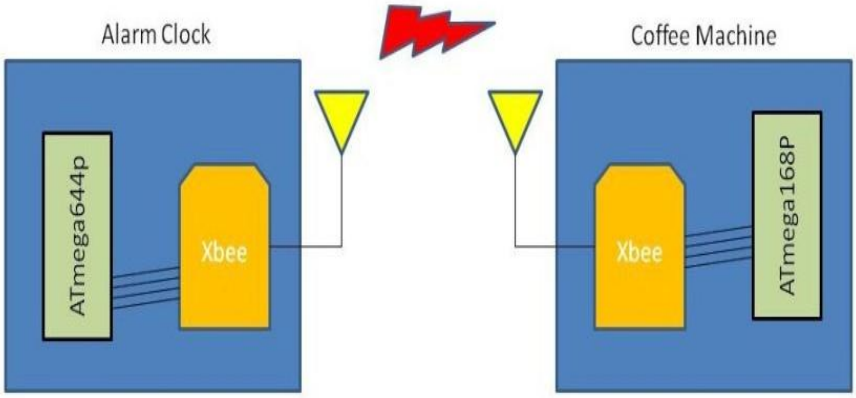

Figure 7.0.2.3.1: ZigBee Radio Transmission

Each ZigBee network can support 65,000 nodes with a single coordinator. The ZigBee specification lists the data transmission rate to be 250 Kbps but with transmission overhead the available bandwidth is 94 Kbps which is plenty for our device

.

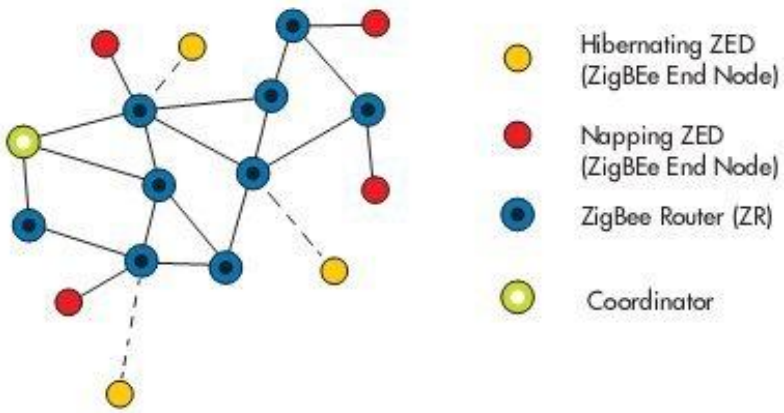

Figure 7.0.2.3.2: Zigbee network node type
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7.0.2.3.1 ZigBee Protocol

ZigBee builds upon the IEEE 802.15.4 standard. They implement four main layers (network layer, application layer, ZigBee device objects (ZDO's), and manufacturer specific application objects) to the MAC and PHY layers.

The ZDO's are the essential core to the ZigBee network. The ZDO layer is accountable for maintaining device roles, security, device discovery, and network joining requests. Beneath the ZDO layer is the network layer.

All routing is managed within the network layer. This layer supports star, tree, and mesh network topologies and will act as three different devices. The first is the ZigBee coordinator (ZC). The ZC is the first required device on the network and will be implemented within the alarm clock. It initiates the network formation by selecting the channel, personal area network ID, and the stack profile. Once the network is formed it will also function as a router for other devices within the mesh. It can also act as a bind controller which will prevent other devices from joining the network without acknowledgment from the ZC. The ZigBee Router (ZR) will be the ZigBee component in the appliance module. It is an optional component in the ZigBee network which acts as a fully functioning device and a network router to extend the range of the network. The router manages its network table for devices within range and allows neighbor routing for those devices. If a ZigBee end device (ZED) is a child of the router it will hold information for the ZED until it wakes up.

The ZED unit is also an optional device which is optimized for very low power operation. It relies on its parent node to let it sleep. It can be associated with either the ZC or the ZR but will not allow associations with other child nodes. There are multiple providers of development kits and devices using ZigBee radios. In our research the devices were narrowed down to three different devices based on availability, price, customer support, and ease of development. Initially it was intended that the product was to be ZigBee compliant using the

Home Automation Public profile but found that development costs were too high for this and chose to use just the IEEE 802.15.4 specifications.

7.0.2.4.1 CC2430

Texas Instruments provides the largest number of ZigBee compliant devices and development kits. The evaluation helped to narrow the selection down to the CC2480 as it is the chip included with the eZ430-RF2480. The development included an MSP430 coprocessor chip CC2480 radio. This was our initial choice until software development costs were investigated. Texas Instruments provides their “Z-stack API” library for product development but no IDE for programming. Texas Instruments in partnership with IAR provide and IDE which integrates with Texas instruments API but even with student discounts was $800.00. As the design was to be low cost this immediately eliminated any product from Texas instruments.

7.0.2.4.2 XBee

Our second choice was the XBee radio developed by Digi International Incorporated. The chip provides UART communication using 802.15.4. The XBee-PRO ZB (figure 7.0.2.4.2.1) was the chosen module as it is ZigBee compliant if the group chooses to implement ZigBee compliance later on in our design and met all of our requirements for radio transmission.

Figure 7.0.2.4.2.1: XBee Radios
Reprinted pending permission from Digi International.

For the appliance module, the microcontroller could use the provided digital I/O pins but opted for UART communication between the modules and the microcontrollers for potential upgrades to the system.

Pin #	Name	Direction	Description
1	VCC	-	Power Supply
2	DOUT	Output	UART Data out
3	DIN/Config	Input	UART Data in
4	DO8	Output	Digital Output 8
5	Reset	Input	Module Reset
6	PWM0/RSSI	Output	PWM Output 0 / RX Signal Strenght Indicator
7	PWM1	Output	PWM Output 1
8	[reserved]	-	Do not connect
9	DTR/Sleep_RQ/DI8	Input	Pin sleep Control Line or Digital Input 8
10	GND	-	Ground
11	AD4/DIO4	Either	Analog Input 4 or Digital I/O 4
12	CTS/DIO7	Either	Clear-to-Send Flow Control or Digital I/O 7
13	On/Sleep	Output	Module Status Indicator
14	VREF	Input	Voltage Reference for A/D Inputs
15	Associate/AD5/DIO5	Either	Associated Indicator, Analog Input 5 or Digital I/O 5
16	RTS/AD6/DIO6	Either	Request to Send Flow Control, Analog Input 6 or Digital I/O 6
17	AD3/DIO3	Either	Analog Input 3 or Digital I/O 3
18	AD2/DIO2	Either	Analog Input 2 or Digital I/O 2
19	AD1/DIO1	Either	Analog Input 1 or Digital I/O 1
20	AD0/DIO0	Either	Analog Input 0 or Digial I/O 0

Table 7.0.2.4.2.2: XBee Pin Assignments
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The XBee ZB modules have an indoor range of 133'. Adding more devices to the network can increase the network range but using a single module for the network should be adequate for most households. Transmit and peak current are each at 40mA while the power-down current is less than 1 µA. The module handles all the data communication and is self healing. If a node in the system fails, the module will automatically seek another node to rejoin the network. The modules support serial communication speeds of 1200-230400 bps (and non-standard baud rates). They also provide small buffers to collect received serial and RF data. Since the data packets will be small, overflow should not be a problem with the system. Overflow can occur if the module receives a continuous stream of RF data and the transmit buffer is also being overloaded. Another problem can occur if the network link is not established and the buffer is continually loaded with data to transmit. In order to prevent the errors, the system will not send any serial data until network links are established and as previously mentioned data transmissions will be short.

7.0.3 Implementation

The XBee modules as indicated above are only transmitting serial data over the ZigBee end devices. Each XBee module is connected wirelessly to a microcontroller. The devices will be pre-programmed at set channels and data rate. In order to configure the devices for serial commands they will be connected to a USB to serial converter board which is configured to work with the XBee module. Sparkfun distributes a PCB with an integrated USB to serial converter and provides the pin headers for the non standard XBee modules. Each device was configured before insertion into each device and with the two

separate XBee explorer USB devices and tested as mentioned in the test plan section and configured as follows. Maxstream, the manufacturers of the XBee module, provides software named X-CTU which is used to configure the modules. XBee configuration is started with the command '+++'. Once the XBee transmits 'ok', configuration data was sent to the module. Once each configuration level is sent, the configuration parameter was checked by sending the same command without the parameter. If configured correctly, the entered data should was echoed back to the console.

The default settings allow other XBee modules to communicate with one another and prevents interference from other modules or in the event that another user is using the same configuration parameters, the settings will be customized. There are multiple parameters for each of the modules to talk to each other. Each of the parameters needs to be configured and saved to ensure proper communication. Each module must be on the same network by setting the ID parameter (see configuration below for details on setting the parameters). The modules must also be on the same channel by setting the CH parameter. The baud rate of each device must also be set at the same rate. The group opted for a transmission speed of 9600 bauds as this does not require buffering in the Xbee module. Finally, each module's destination address (destination high (DH) and destination low (DL)) must be configured. These parameters determine which modules on the particular and network and channel will receive the data it transmits. The destination high and destination low parameters can be configured in a few ways:

- If a module's **DH** is 0 and its **DL** is less than 0xFFFF (i.e. 16 bits), data transmitted by that module will be received by any module whose 16-bit address **MY** parameter equals **DL**.
- If **DH** is 0 and **DL** equals 0xFFFF, the module's transmissions will be received by all modules.
- If **DH** is non-zero or **DL** is greater than 0xFFFF, the transmission will only be received by the module whose serial number equals the transmitting module's destination address (i.e. whose **SH** equals the transmitting module's **DH** and whose **SL** equals its **DL**).

7.0.4 Configuration

The available configuration options available for using the XBee modules are listed in table 7.0.4.1. There are other commands supported, but the XBee module will only be used as a virtual serial port between the microcontrollers, only the options listed below will be used.

Command	*Description*	*Valid Values*	*Default Value*
ID	The network ID of the XBee module.	0 - 0xFFFF	3332
CH	The channel of the XBee module.	0x0B - 0x1A	0X0C
SH and SL	The serial number of the XBee module (SH gives the high 32 bits, SL the low 32 bits). Read-only.	0 - 0xFFFFFFFF (for both SH and SL)	different for each module
MY	The 16-bit address of the module.	0 - 0xFFFF	0
DH and DL	The destination address for wireless communication (DH is the high 32 bits, DL the low 32).	0 - 0xFFFFFFFF (for both DH and DL)	0 (for both DH and DL)
BD	The baud rate used for serial communication with the Arduino board or computer.	0 (1200 bps) 1 (2400 bps) 2 (4800 bps) 3 (9600 bps) 4 (19200 bps) 5 (38400 bps) 6 (57600 bps) 7 (115200 bps)	3 (9600 baud)

Table 7.0.4.1: Common Serial Configuration Parameters
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Serial communication is transmitted at 9600 baud using the configuration command ATBD 3. The channel for each module will be for the alarm clock and the appliance module 0x11. Any additional XBee devices will be configured with same channel ID as this is required for communication over the network. The network ID is configured by sending the command ATID XXXX, where XXXX is the ID number in the range of 0 to 0xFFFF. Initially this will be set at a static value of 0xAAAA. If the alarm clock system goes to market, the alarm clock master ZigBee module can be set to scan for any transmitting channels, but this was not implemented in the current system. If one is found, this channel would be eliminated from the selection as the alarm clock would be functioning as the master controller and another channel is chosen. Again if the product went to manufacturing, the appliance module would be set to scan all the network channels and look for the alarm clock and send commands with expected return values. As noted in the table 7.0.4.1, DH and DL settings are specific to the operation of the modules. The alarm clock, acting as the master controller, has the DH address as 0 and DL as 0xFFFF. The appliance modules DL and DH addresses also has the same initial address as the alarm clock. Using the same parameters eliminates any link communication problems. Of course this will need to change if the device does go to market. As a note, once all the configuration parameters have been set, the command ATWR is sent to the XBee module and the configuration parameters are written to NVRAM on the module. Once this is done, the XBee modules are connected to each of the respective microcontrollers. As there will be different microcontrollers, each separate implementation is listed in the following sections.

The alarm clock uses an ATmega644p which provides two separate UART pins. The LCD module is connected to one set and an XBee module is connected to the second set. On the microcontroller, pin 16 (RX1) will go to pin 3 (DIN/CONFIG) on the XBee module. Pin 17 will be connected to pin 2 (DOUT) on the XBee module. These two pins handle the data transmission. For power, pin one is VCC and connected to a 3.3V source and pin 10 is connected to the common ground of the system. All interface and link information for the Xbee module is displayed on the OLED module in the setup screen. The appliance module is hooked up in the same manner as the alarm clock system. The microcontroller runs at 5 volts and the XBee module runs at 3.3 V. As the Xbee module is the only device requiring 3.3 volt and is powered by a separate linear voltage regulator. Pin 7 is hooked to power and pin 1 is hooked to power. The common ground is connected to pin 10 on the XBee adaptor and pin 8 on the microcontroller. For the appliance module, transmit (pin 11) on the microcontroller will be connected to receive (pin 2) on the XBee module. Receive on the microcontroller is pin 12 and it will be connected to pin 2 on the XBee module. There will be two LED's on the appliance module. The first will indicate if the appliance module is in the "ON" state. This LED will be connected to a digital output pin on the microcontroller. This will give an indication to the user that the system has successfully linked up. The details of the appliance module are in section 7.2.

7.0.5 Testing

The microcontroller will only be using the UART mode of the XBEE modules. For testing the function and communication, two Xbee were use. One was connected to a USB to serial adaptors and the other to the microcontroller. The Xbee modules were configured as listed in the implementation section above. Using a windows DOS terminal and the microcontroller, a set sequence of characters were sent and a series of commands and which were verified with the terminal server. Range tests were performed up to a range of 150 feet to ensure the specification of minimum range of 100 feet was met.

7.1 Remote Detection Unit

7.1.1 Technical Objectives and Specifications

In order to optimize the wake up time for the user, the group decided to implement a remote detection system. The device would be a wireless transmitter/receiver that the alarm clock would ping at set intervals to detect when it was out of range. Initial suggestions were using a key chain system that would run on battery power. Upon determining the power requirements of the XBee module, this would not be a viable choice as the battery would only last approximately two to four hours depending on the frequency of transmission. The next option would be to place the XBee module within a car. It would be powered off the car battery which eliminates the power system dilemmas.

7.1.2 Goals

The alarm clock will be able to determine if e the user is out of range of the alarm clock system. The alarm clock will be able optimize the wake up time to ensure the user has left the premises by the time specified by the user. The system will be able to detect the differences between device out of range and device failure. The alarm clock software system will be able to determine whether the car transceiver has left range or if it has simply failed.

7.1.3 Input/output

The remote (car) transmitter will simply be powered by the car battery. It will be a standalone device which will be programmed to send short packets to the alarm clock. The XBee modules support RSSI to indicate when the range changes. If the RSSI is decreasing the alarm clock will request transmission frequently to ensure the device is leaving by verifying a progressively decreasing RSSI and making sure it is not just interference or a dropped communication.

7.1.4 Power

Car batteries typically run between 12V and 16V. The XBee module require 3 – 3.4 V for the Pro version. To bring the power down to specifications a LM3703 will be used. It is a linear voltage regulator available from multiple manufacturers and can drop the voltage to 3V. A simple PCB with the voltage regulator and the XBee module would be all that is required.

7.1.5 Software

There is no software requirement for the key chain system. All Zigbee modules support node discovery (ND) operations. The node discovery command can be used to discover all modules that have joined a network. Issuing the ND command sends a broadcast node discovery command throughout the network. All devices on the network that receive the command will send a response that includes the device's addressing information, node identifier string (see NI command), and other relevant information. This command is useful for generating a list of all module addresses in a network. The node identifiers are unique to each module and can distinguish between the appliance module system and the remote sensor unit. When a device receives the node discovery command, it waits a random time period before sending its own response. The maximum time delay can be set on each individual module using the ND command for the sender with the NT command. The ND originator includes its NT setting in the transmission to provide a delay window for all devices in the network. Large networks may need to increase NT to improve network discovery reliability. The default NT value is 0x3C (6 seconds). With only three devices on the network, the default settings will be kept at 6 seconds. There is also an option to have the remote sensor act as a beacon transmitter. In beacon mode, the transmitter could transmit at a random 30 second interval. If the received signal strength was significantly decreased between pings, the transmitter could decrease the ping time by half with each successively decreasing ping time. The

base transceiver (alarm clock) could measure the RSSI with each ping and determine if the receiver were actually leaving the network area.

7.1.6 Research

The research for wireless communication modules was limited to Zigbee devices as Zigbee is already limited in the system. This limits production costs and development costs. The XBee module supports received signal strength indication so the alarm clock will be able to support the distance/range detection. There are a number of other Zigbee modules (including those mentioned in the wireless communication section) that support RSSI. No further investigation was conducted on Zigbee module based on previous investigations and design costs and time.

7.1.7 Implementation

The remote detection unit was not implemented based on time allotted. The following Implementation if at a later time the device should be implemented. As with the other XBee modules the all device configuration will occur prior to installing it. The device only requires power to function. It will only support node discovery. There will be a single LED connected to the remote signal strength indicator pin (pin 6) to ensure remote connection to the GuSu alarm clock system. It will be lighted when a connection is present. The remote detection unit will be mounted in a sealed plastic enclosure and will have an external 12V cigarette power adaptor to be plugged into the automobile. Being that there are very few components in the system, it will be mountable in a small enclosure. The soap box enclosure (figure 7.1.7.1) available from Sparkfun.com will be large enough to contain all of the devices.

Figure 7.1.7.1: Soap Box Case for remote detection unit
Reprinted with permission from Sparkfun Electronics.

Since the remote sensor system will not include a microprocessor all of the processing will be performed at the master controller unit (alarm clock). The alarm clock will send out the network discovery command every thirty seconds. If the remote module is determined to be in the process of leaving the network by measuring a decreasing RSSI signal strength, the alarm clock system will decrease the ping time to 6 seconds. It will not be set lower than six seconds as

this is the timeout period for the network discovery command. Once three successive pings have been acknowledged with three successively decreasing signal strengths have been received, the system will consider that the node has left the network. In order to minimize the network traffic the ping time will be set to 30 minute intervals during non alarm time interval. The alarm time interval will be defined as the time period between 30 minutes before alarm wake up time to an hour and a half after alarm trigger. The circuit is quite simple (figure 7.1.7.2) and will be built with a perfboard as it only requires four components.

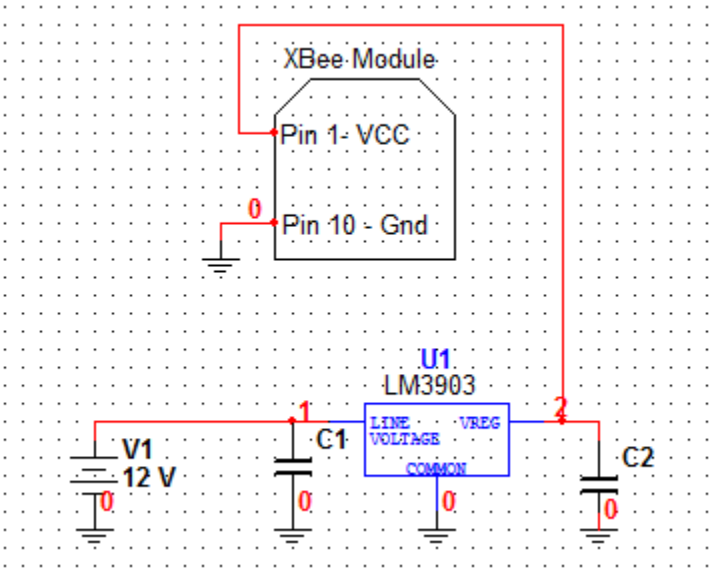

Figure 7.1.7.2: Circuit diagram for remote Detection Unit

7.2 Appliance Module

7.2.1 Technical Objectives and Specifications

7.2.1.1 Goals

The appliance module with an external plug and two receptacles will be used. The appliance module will be externally connected over a wireless ZigBee mesh network. All communications with the device will be over secure network communications which will prevent the appliance module from turning on at random periods. The appliance module will be controlled with microcontroller and communicate with the alarm clock via UART to the XBee module. There will be a single button on the appliance module to locally toggle the module on and off for unscheduled activations. There will also be a single LED to indicate power on and ZigBee link status.

7.2.1.2 Input/output

With only a single button and a single LED only two digital IO pins will be required. For the XBee Module the alarm clock microcontroller will need a single UART port on the microcontroller. To activate the receptacles appliance module will need a digital relay to enable the external appliances.

7.2.1.3 Power

The microcontroller requires DC power and AC power is required for the external appliances. In order to limit the wires coming into the device, a dc voltage converter will be placed within the system case. Three options were investigated for AC/DC conversion. The first device investigate was a full wave rectifier with DC voltage regulators, transformers with voltage regulators, and switched mode power supplies are the researched options. Batteries could also be used to power the DC components but even with every DC electronic system in lower power state, the system would last only approximately 3 days before requiring new batteries. As we want to limit the size of the component case, smaller devices were investigated. The smallest switching mode power supply found during the research was approximately 2'' x 2''. With the microcontroller and XBee module already occupying the limited space the group felt that the module power supply could be installed externally if necessary. As the coffee machine has not been obtained yet, this will be investigated further during development. The group consensus is to currently supply the DC power via a second power source. An AC/DC transformer can be housed external to the system and heat problems will also be eliminated. The same power design implemented with the alarm clock system could be used to power the microcontroller at the full 5V and a step down voltage regulator could be inserted to power the XBee module at the require 3.3V. The other option would be to power both the XBee module and the microcontroller at 3.3V as previously mentioned with a single 3.3V DC wall wart. If the power problems prove difficult to implement, there are multiple manufactures which produce ZigBee compatible relay switches which can be controlled by the alarm clock.

7.2.1.4 Software

The software will only need to handle controlling simple communication with the XBee module and enabling and disabling three separate I/O Pins. As discussed in the Clock System, by using similar microcontrollers the group will be able to save time and money in development and cost. By using a similar architecture the group will not need to learn new programs for development and buy separate development boards.

7.2.1.5 Physical Package

The microcontroller for the alarm clock includes a number of pins and features that are not necessary for the clock but ATMEL makes a number of microcontrollers that support the same 8-bit RISC architecture with smaller footprints.

7.2.2 Research

Since the group will be restricting the microcontroller to an Atmel device the following device topologies from Atmel will be contrasted. The first device is the ATiny 2313.

7.2.2.1 ATtiny 2313

The Atmel ATtiny 2313 met the requirements all of the requirements set forth in the previous section. It is capable of handling UART communication with the XBee module and has multiple digital I/O pins for controlling the relay. It can also be powered at the same voltage as the XBee module. The ATtiny 2313 is an 8 bit RISC processor with 2 Kbytes of in system programmable flash memory. It can operate from 0-20 MHz on a voltage range of 1.8V – 5.5V. There are 20 pins total with programmable I/O pins for connecting to the relay for the heater element and the LED lights for user updates. There is a single UART port for communication with the XBee module. The only negative factor is the programming of the microcontroller. Atmel provides an IDE to develop for the board in either C or Assembly languages. The group is leaning towards using the open source Arduino boot loader so this eliminates this microcontroller as it is not compatible with Arduino.

7.2.2.2 ATmega168

As this microcontroller is similar to the ATmega644, only the finite details/differences will be listed in this section. The other Atmel chip researched is the ATmega168 which is compatible with the Sanguino boot loader. The packages available are a 28 pin DIP, 32 pin VQFN, and 32 pin TQFP packages. The DIP package is preferred for its ease in prototyping. It is also an 8 bit RISC microprocessor with 16Kbytes of programmable flash memory and 512 bytes of EEPROM. It supports 131 instructions and 32 x 8 general purpose registers. Like the ATtiny2313 it will operate from 0-20 MHz at a voltage range of 1.8V – 5.5V. A single UART is available for communication with the XBee ZigBee radio modem. There are 23 other I/O pins available for analog or digital signals. A single external interrupt and internal interrupts are also supported. The microprocessor also supports five software selectable power modes (Table 7.2.2.2.1). The power-down mode saves the register contents to NVRAM and freezes the internal oscillator until an interrupt or hardware reset on pin 1. Power save mode keeps the asynchronous timer running while shutting down all other functions on the device. ADC Noise reduction mode allows the microprocessor to shut down all I/O modules except the analog to digital converter to minimize switching noise while sample analog signals. In standby mode the oscillator continues to run which permits fast startups and low power consumption. The idle mode stops the CPU but leaves the USART, SPI, interrupts, SRAM, and the timers running.

	Active Clock Domains					Oscillators		Wake-up Sources						
Sleep Mode	clk_{CPU}	clk_{FLASH}	clk_{IO}	clk_{ADC}	clk_{ASY}	Main Clock Source Enabled	Timer Oscillator Enabled	INT1, INT0 and Pin Change	TWI Address Match	Timer2	SPM/EEPROM Ready	ADC	WDT	Other/O
Idle			X	X	X	X	X(2)	X	X	X	X	X	X	X
ADC Noise Reduction				X	X	X	X(2)	X(3)	X	X(2)	X	X	X	
Power-down								X(3)	X				X	
Power-save					X		X(2)	X(3)	X	X			X	
Standby(1)						X		X(3)	X				X	

Notes: 1. Only recommended with external crystal or resonator selected as clock source.
2. If Timer/Counter2 is running in asynchronous mode.
3. For INT1 and INT0, only level interrupt.

Table 7.2.2.2.1: Power Modes for ATmega microcontrollers
Reprinted pending permission Atmel.

7.2.3 Implementation

The Atmega168 was used and will be running at 5 volts. The Atmega168 provides a single 3v3 output pin so the Xbee module will be powered from the microcontroller. The microcontroller communicates with the XBee module using UART pins 11 and 12, RX and TX respectively. It will also be connected to an LED with a single Digital output pin. The led will indicate to the user that the appliance module is in the ON state. A single relay will also be connected to a digital output pin of the microcontroller. As most motors and relays are inductive, they shouldn't be connected directly to a microcontroller because they may require more current than a microcontroller can safely supply. The requirements for the relay are 3.3V and can tolerate 10 amps. The standard home plug supports 15 amps but most devices do not draw such a large load. According to the U.S. Department of Energy, the average coffee maker consumes 800 - 1200 watts. This equates to 6.7 to 10 Amps. The option of plugging in a coffee machine was investigated and this is the reason a 10 amp relay was chosen.

In order to protect the microcontroller from the inductive loads a transistor was used as a switch to prevent damage to the microcontroller during relay switching. A diode is also needed to protect the microprocessor from back EMF current and is placed in parallel with the relay and the power supply (figure 7.2.3.1).

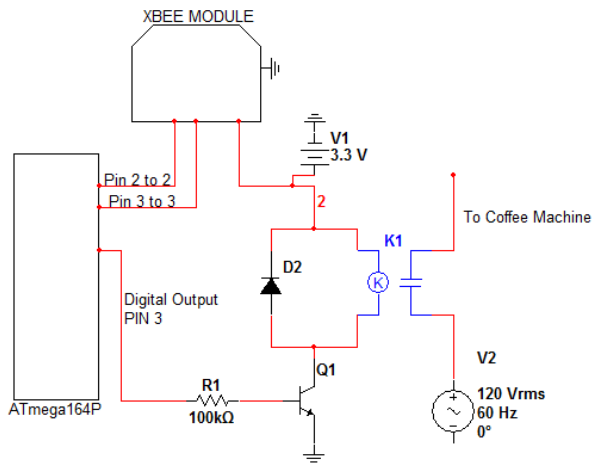

Figure 7.2.3.1: Circuit Diagram for Appliance Module System

There are multiple DC relays available for the appliance module system. The relay chosen during research was the Omron G6C-2114P-US-DC5. It can handle a resistive load at 10 amps and 240 VAC. The software for the system is very simple. Once power is applied to the appliance module system, the XBee module joins the network using previously defined connection settings which is described in the Radio communication section. The system then goes into low power idle mode waiting for user input from the local power toggle or a transmission from the alarm clock. The system awakens by the internal interrupts on the UART. The activity diagram below (figure 7.2.3.2) outlines the functions of the system.

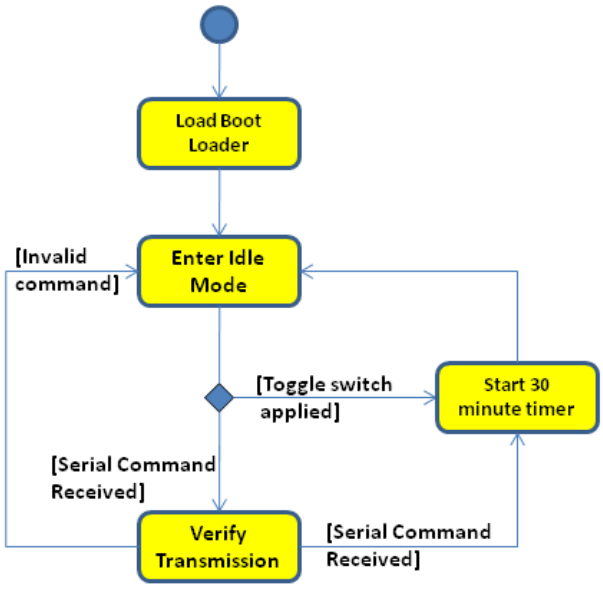

Figure 7.2.3.2: Activity diagram for appliance module

As you can see, the appliance is quite simple. Verifying transmission is handled by echoing back the message to the alarm clock system and receiving the same instruction previously received. There is also a key assigned to each device which is unique to each pair. This assists in preventing false triggers and thus potential fires.

7.2.4 Testing

The microcontroller was booted and serial communication was tested with a terminal server and a PC. An LED was hooked up to toggle with the relay to indicate on and off status of the device. Since the system is quite simple, the code will be developed and completely tested on the system using a terminal server. Timeout verification will be verified by sending an on command and confirming that system has returned to idle mode and confirming that the LED is off. The local button was tested to ensure on/off of the relay controlled device also was controllable.

8.0 Clock Module

8.1 Goals and Objectives

The alarm clock system will need to maintain accurate time with little drift. It will also require the ability to maintain a minimum of two alarms to be stored in the system. These can be stored externally or in NVRAM on the microcontroller.

8.2 Research

Two different clock modules were investigated for the system. Ideally the atomic clock was to be implemented as it would limit the need for user interface design and contribute to the ease of use. Since there is limited availability atomic clock modules real time clock modules were also investigated.

8.2.1 Atomic Clock

WWVB broadcasts a radio time signal from the National Institute and Technology (NIST) in Fort Collins, Colorado. The signal transmits both time and date 22 hours a day. Using a radio receiver the clock can automatically set itself. The radio clock module would, in the event of power failure/loss, transmit the correct date and time to the microcontroller without requiring the user to set the time. This would simplify the programming of the microcontroller by limiting the implementation of the user interface. The most desirable choice but the availability of clock modules is very limited. In fact, only one such module could be found that was available for purchase. This was the CME6005 made by C-Max Time Solutions. It is an IC that requires external antennae design and fabrication and research has shown that the device is fairly unreliable. The cost of the radio clock module and complexity of including it in our design is also

much greater than a real time clock module eliminating this option from project consideration.

8.2.2 Real Time Clock

The alarm clock will contain a real time clock (RTC) module. This will allow the clock to maintain time, date, and alarm settings in the event of power failure. The RTC will also provide a number of integrated features which can be used in our system. The countdown timer can be used to begin counting when the alarm goes off and gradually increase the volume of the alarm until the user gets out of bed. There are many interfaces available but in order to keep the complexity and cost of the system low, the group opted for a real time clock with an SPI interface. As with the other components, a dual inline package will be chosen.

Two devices meet our requirements. The first is the DS-1307N (figure 8.2.2.1) available from Dallas Semiconductor and the Intersex CDP68HC68T1. Each module meets all of our requirements. The DS-1307 provides a few more features such as dual alarms and costs half as much as the Intersil module. Clearly the choice will be the least expensive module with more features.

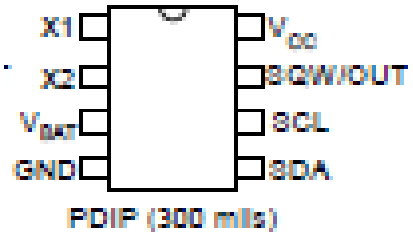

Figure 8.2.2.1: DS-1307 Pin Diagram
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The DS-1307 is an 8 pin DIP with a clock/calendar which provides seconds, minutes, hours, day, date, month, and year information. All of this data is accessible over the I^2C interface. The module also provides 96 bytes of NVRAM for storing data such as alarm settings. The alarms can be set to output a single or different interrupt in the event of an alarm condition and can be operated under either of the available alarm conditions. Dual–power systems are supported allowing for a backup battery in the event of power failure and the V_{BAT} pin outputs a programmable trickle charge permitting the use of rechargeable batteries (figure 8.2.2.2). The operating voltage is from 2.0V to 5.5V which falls within the range of other modules within the system.

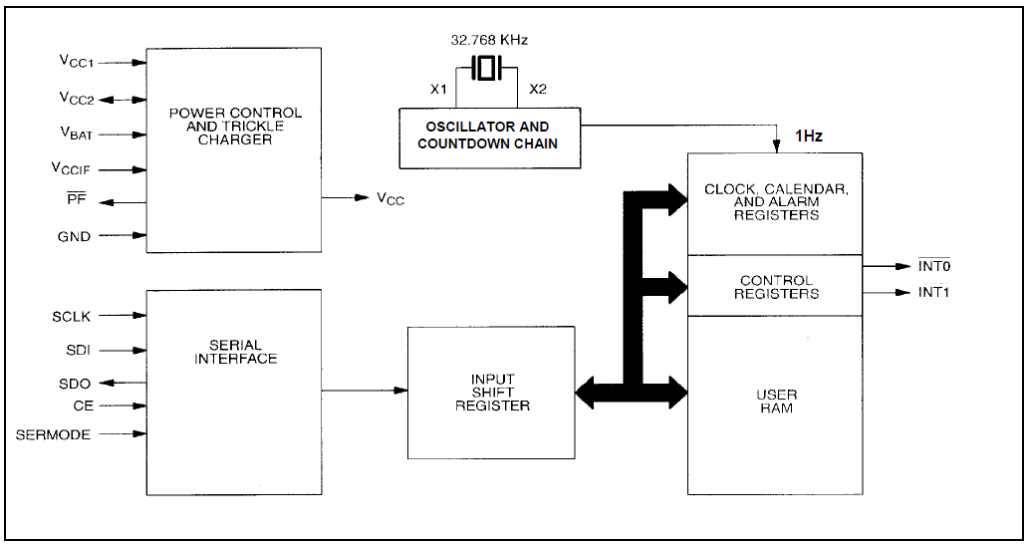

Figure 8.2.2.2: Block Diagram for DS-1307
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The clock, calendar, and alarm times can be obtained by reading the appropriate register bytes. The time settings are initialized by writing to the specific register bytes. The contents of each register are stored in BCD format. The day values are stored as sequential user defined numbers. For example, if the 1 equals Sunday then Monday would be the next sequential value of 2. If any of the register values are improperly set, the operation of the clock is undefined. The DS1307 can operate in either 12-hour or 24-hour modes. In order to configure the hour mode bit 6 is toggle high or low. When high, 12-hour mode is selected. The rest of the register settings are listed in table 8.2.2.1.

HEX ADDRESS		Bit 7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0	RANGE
READ	WRITE									
00H	80H	0	10 SEC			SEC				00–59
01H	81H	0	10 MIN			MIN				00–59
02H	82H	0	12	P/A	10-HR	HOURS				01–12 + P/A
			24	10						00–23
03H	83H	0	0	0	0	0	DAY			01–07
04H	84H	0	0	10-DATE		DATE				1–31
05H	85H	0	0	10-MONTH		MONTH				01–12
06H	86H	10-YEAR				YEAR				00–99
07H	87H	M	10-SEC ALARM 0			SEC ALARM 0				00–59
08H	88H	M	10-MIN ALARM 0			MIN ALARM 0				00–59
09H	89H	M	12	P/A	10-HR	HOUR ALARM 0				01–12 + P/A
			24	10						00–23
0AH	8AH	M	0	0	0	0	DAY ALARM 0			01–07
0BH	8BH	M	10 SEC ALARM 1			SEC ALARM 1				00–59
0CH	8CH	M	10 MIN ALARM 1			MIN ALARM 1				00–59
0DH	8DH	M	12	P/A	10-HR	HOUR ALARM 1				01–12 + P/A
			24	10						00–23
0EH	8EH	M	0	0	0	0	DAY ALARM 1			01–07
—										
0FH	8FH	CONTROL REGISTER								—
10H	90H	STATUS REGISTER								—
11H	91H	TRICKLE CHARGER REGISTER								—
12–1FH	92–9FH	RESERVED								—
20–7FH	A0–FFH	96-BYTES USER RAM								—

Table 8.2.2.1: DS1307 Registers
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The DS1307 also contains two times of day alarms which can drive two external interrupts. The alarm times are set by writing to registers 87h to 8Ah for alarm 0 and registers 8Bh to 8Eh for alarm 1. The alarm clock will be using two alarm clock settings for days of the week. The module supports five different settings for alarm time/day triggers by setting bit masks in each alarms respective registers. The five settings are alarm once per second, when seconds match, when minutes and seconds match, when hour's minutes and seconds match, and when day, hours, minutes, and seconds match the set time. During each clock update, the RTC clock compares both alarm 0 and alarm 1 registers with the clock registers. If a match occurs, the corresponding alarm flag bit is set to 1. If the corresponding alarm interrupt is enabled, the external interrupt is driven high. Data is transferred between the microcontroller and the RTC when the CE pin is driven high. A single byte is transferred per clock cycle of SCLK at the shift edge when selecting read or writes to/from registers. Address and data bytes are shifted MSB first. All transfers require address of the byte to indicate write/read to the RTC or to the memory location which is followed by the data. Once the register has been selected the data can be read in burst mode. Each read/write cycle causes the RTC to automatically increment each data member in the register until the device is disabled (setting CE low). One precaution is that while reading or writing in burst mode, the address pointer will wrap around after reaching 1Fh for reading and 9Fh for writing to the clock. It will also wrap around when accessing the RAM after reaching 7Fh for reading and FFh for writing.

8.3 Implementation

The DS-1307 is available in an 8 pin dual-inline-package making it easy to integrate into the PCB. The alarm clock system design includes a battery backup module for the entire system so V_{BAT} (pin 2) will be used and the pins for battery charging will be left open. The module requires a 32.768 Hz crystal to be connected to X1 and X2, pins 3 and 5 respectively. Pin 8 provides a 32.768 Hz output that can be used throughout the system but is not implemented as the microcontroller's max frequency is 20MHz. If the alarm settings are to be implemented in the clock module, both interrupt pins can be used independently from one another. As the group opted to have a seven day programmable alarm, the interrupts were not used. Pins 7 and 8 on the DS-1307 are the I^2C pins are connected to pins 15 and 16 of the microcontroller.

8.4 Testing

The clock module will maintain the critical function for the alarm clock in keeping time. All used functions of the module were tested thoroughly. Since the alarm clock system was using an I^2C interface, the module was tested by hooking it up to the ATmega644p pins 16 and 17 (I^2C interface) after the microcontroller has been tested. All pins will be wired as indicated in the implementation described above. The clock time was set and power was applied for 24 hours. Once the time has elapsed, the module time was compared with a synchronized clock on a nist.time.gov (an online official time clock from the U.S. government which is accurate within 0.2 seconds.)

9.0 Power Supply

The alarm clock requires power to operate, and this section is dedicated to the supply and backup storage of that power.

9.1 Block Diagram

Below (figure 9.1), is a very top-down block diagram of the power system of our alarm clock. The two main components of note in the design of this section would be the Power Supply and the Battery Backup.

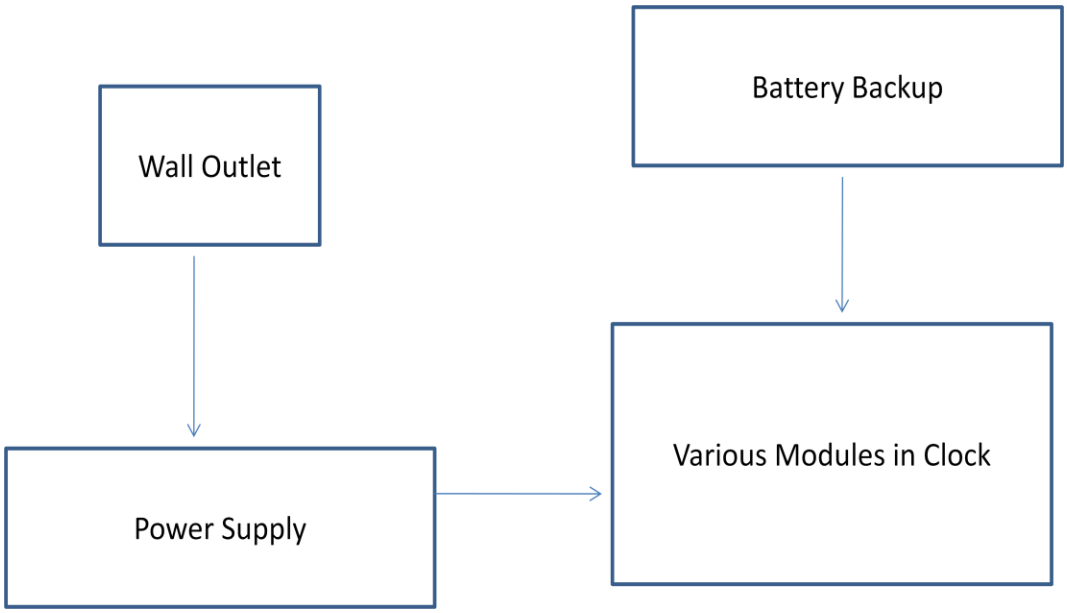


Figure 9.1: A block diagram of the "power system."

9.2 Power System

9.2.1 Power Supply

The alarm clock is powered through power available from wall outlets. This voltage is regulated to a DC voltage of around 3.3 and 5V, the values chosen due to the needs of the clock components.

9.2.1.1 Research

Of course, everything in the electronics world needs power. In this project's case, every component from the microcontroller, the tuner, and everything in between, will need to be powered by DC current with a voltage of 3-5V. Because America (and much of the rest of the world) generates AC power for distribution, that power must be converted from AC to DC. This can be done in a variety of ways, but first it is important to understand how it works.

The first step in any power supply is to convert the 110V AC voltage to a DC voltage, preferably somewhere between 9V and 15V [53]. This is often done with something known as a 'wall wart,' or with a power brick. These are basically the same thing; the main difference is that wall warts plug into a wall and output the desired voltage directly out form there through the cord, whereas power bricks are fed a line from the wall to the device where the A to D conversion takes place. This is then fed through a second line to the device that is consuming the power. The main advantage of wall warts would be the easier design, and it only needs one cord. Another advantage is that is keeps any heat from the conversion right next to the wall outlet, and far from the device. While power bricks can be kept from the device as well, a user that does not know any better

could set the power brick directly by it or under it. The main advantage for power bricks, however, would be that they do not take up any more space on the outlet than necessary. Oftentimes, wall warts can be quite bulky, blocking access to other plugs that could use the same outlet. The same is true of plugging them into power strips. An example of both the wall wart and the power brick is shown below in figure 9.2.1.1.1.

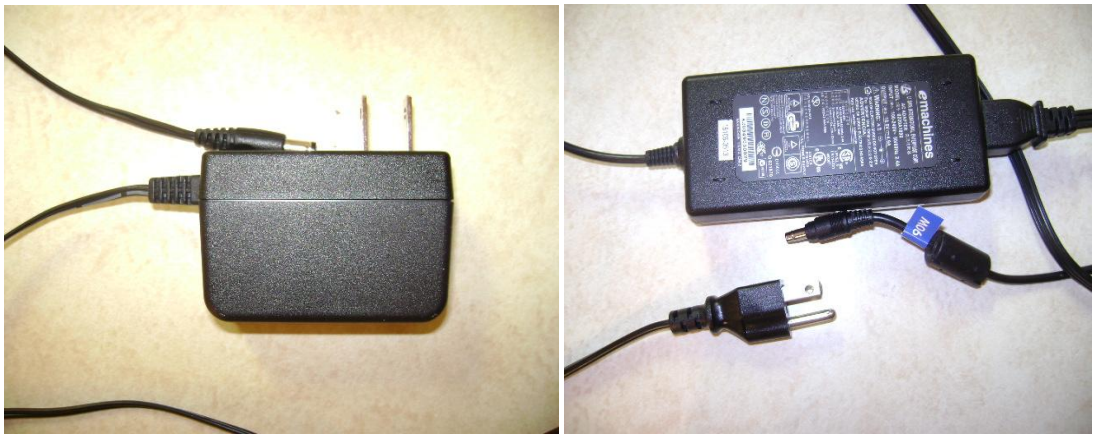


Figure 9.2.1.1.1: Both a wall wart (left) and a power brick (right). Notice how the wall wart could potentially block access to a lower outlet, depending on its physical configuration.

Wall warts or power bricks for this project could come from a variety of places. Many home appliances use them, and one could rather easily be scavenged for use in this alarm clock. Each one plainly and simply states the input and output voltage and current levels. It was important that a suitable one was used. For example, one with too high of a voltage level would likely not cause too much of an issue (see below about regulators), but one that does not output enough current could cause problems. They can also readily be found online. For example, many wall warts were able to be found for under 20 dollars on Amazon.com, with outputs ranging from .5A to 2.5A [54]. Power bricks are readily available online as well, with an example of a 12V power brick being available from store.mp3.com for $29.99 [55]. The many options will make the choice a somewhat simple one. For the GuSu alarm clock project, it really does not matter if the group uses a wall wart or a power brick. The important thing will be that it supplies a decent voltage, and enough current to supply all of the components.

The voltage that comes from this wall wart (or power brick) is a noisy voltage, somewhat around what is specified. For example, a 9V wall wart will not give exactly 9V; more likely it will rise and fall somewhere between 8.5 to 9.5 V [53]. This somewhat-DC voltage needs to be both dropped down to the needed voltage (around 3.3V to 5V), and cleaned up (so it will be a steady, flat voltage rather than one with ripples). This can easily be accomplished with the use of a regulator.

A 5V regulator could take any DC voltage from roughly 7V to about 34V and output that voltage at 5V [53]. A very common part for this task is the LM7805. The first pin on the regulator would be connected to the input voltage from the wall wart, the middle pin to ground, and the output pin would be 5V. Now if the input to the regulator is a noisy 9V, the output would be a noisy 5V. This can be fixed using capacitors to smooth the voltage levels. Without heavily going into the physics of capacitors, they basically provide stability to the voltage level, by absorbing energy when the voltage is high and expelling energy whenever the voltage is low. As long as the voltage is not dropping out for considerable periods of time (power outage), and there are not significant spikes in the voltage levels, the capacitors will keep the voltage to a steady 5V. The higher the capacitance rating of the capacitor (in Farads), the more energy it can store, meaning the more it can release. However, the higher the capacitance, the slower the storing and releasing of energy takes place, and vice versa. So, with most regulators, it is important to place larger capacitors in the range of 10 to 100 micro Farads on the power rail [53]. These capacitors help to hold the voltage up if the power falls for a short time (about 10 to 100 ms). An example of the previously mentioned LM7805 5V regulator is shown below in Figure 9.2.1.1.2, with the 10 uF and 100 uF capacitors on the 5V and 9V sides of the regulator.

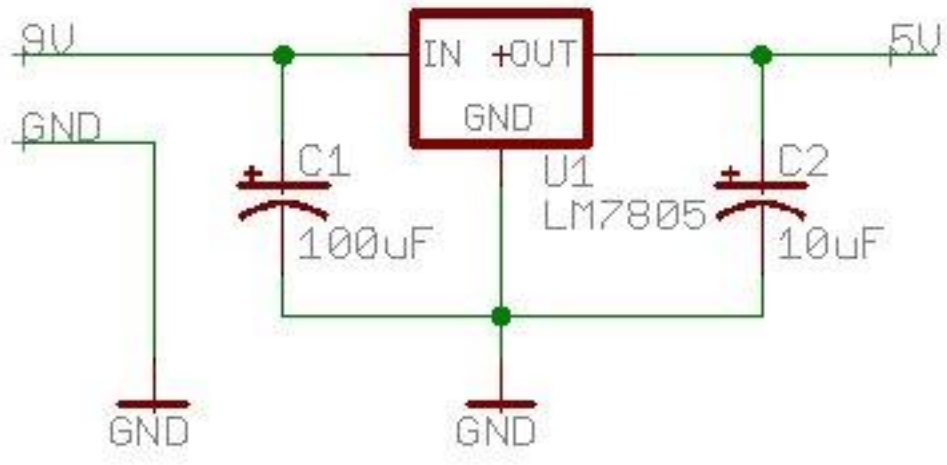


Figure 9.2.1.1.2: LM7805 regulator with capacitors.
Reprinted with permission from Sparkfun Electronics.

These voltage regulators are rather easily found online. From the Sparkfun Electronics website, a LM7805 5V regulator with a max current flow of 1.5A is available for $1.25 [53]. An LM78M05CT 5V regulator with max current flow of .5A is available from www.national.com for a mere $0.58 [56]. However, these come with minimum orders of 45, so that would not be very feasible. Many companies offer samples of these, and some requests could be put out if the group believed that it was needed. There is a wealth of other companies selling similar voltage regulators for similar prices, and it would mainly be very important that the regulator purchased for this project could support as much current

flowing through it as the clock would need. However, the alarm clock should not need more than 500mA of current.

According to Sparkfun Electronics, it is also very helpful to place a diode at the 9V receiving end to ensure that the current will only flow in one direction [53]. This can be important in some instances where the connection might be made many times, or by the user. This would prevent the accidental incorrect wiring of the voltage line and ground, resulting in a reversing the polarity of the voltage, and thus the direction of the current. However, because this part of the project would not be touched by the user, the diode would not be a necessity. It will just be important for the group members to keep the voltage and ground lines straight during development.

One thing that would be very handy, however, would be a way to know whether or not the power is on. An indicator of sorts would be nice to have, so if there were ever any problems during testing (which is very possible), rather than having to check the voltages with a multimeter each and every time, it would be nice to see a straightforward visual indication. This can rather easily be done by using a light-emitting diode (LED). Without going explicitly into how LEDs work, suffice it to say that they emit a small light when a small amount of current flows through them. In general, LEDs should never have more than 20mA of current flowing through them, as around that point they begin to fail [53]. The easiest way to ensure the reduced current in the LED is to put it in series with a resistor. The resistor would be chosen, of course, based on the voltage. So if there was a 5V regulator, and someone wanted to know how to tell if that regulator is truly outputting about 5V, an LED and a resistor could be wired in series from the 5V voltage level to ground. In this example, the resistor to be chosen would probably be about 330 Ohms. Using Ohm's Law that would create a current of about 15mA, which would be more than enough to light the LED. Now, if there were ever significantly less than 5V coming out of the regulator, the LED would be off to indicate that. Chances are the voltage out of the regulator would be nearly 5 or nearly 0. Because of that, if the light is lit up, than there is a good chance that if anything is wrong, it is not the power supply. An example of a circuit with the LED installed is shown in Figure 9.2.1.1.3:

Different colored LEDs can be found for prices that approach being free with minimal searching. A quick search of SparkFun Electronics found red and yellow LEDs for only $0.50 each [53]. There are many other suppliers, and it could be added to any other orders from most electronics websites.

The "build it yourself" method outlined above would not be too difficult. It would require some PCB space, possibly its own small board for the regulator. It could probably be integrated onto another board to save size and cost, however. The regulated voltage, if chosen to be around 5V, could then be stepped down as needed to power the lower voltage elements that exist in this project.

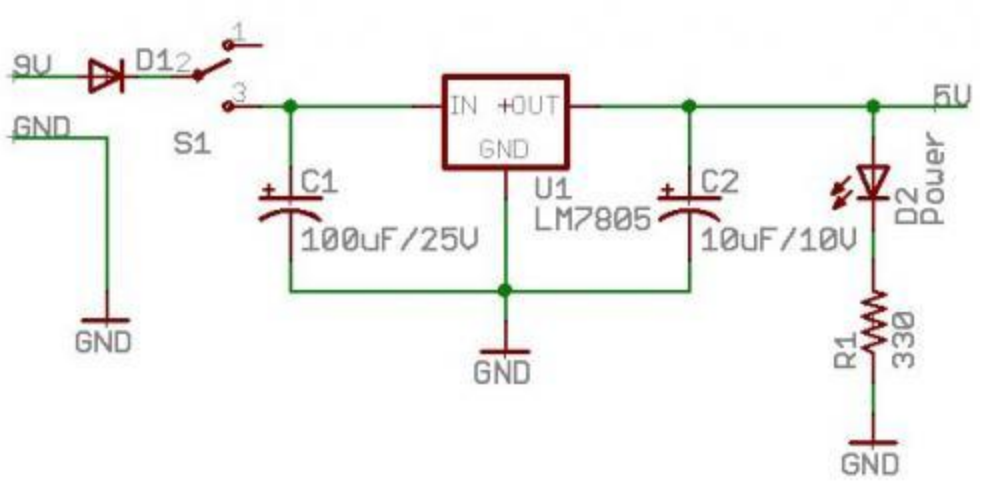


Figure 9.2.1.1.3: The LM7805 regulator with capacitors, a switch, and the LED installed. Notice that it makes no difference whether the resistor or the diode is placed first in the series. Reprinted with permission from Sparkfun Electronics.

Another option for the power supply would be to feed pure 110V AC voltage into a PCB that included an all-in-one Analog to Digital converter, which should output a regulated voltage at the level needed for this project. A search of Acopian Power Supplies, a well-known power supply delivery company, shows all-in-one PCB parts with a regulated 5V output ranging from $79.00 to $97.00 [57]. These prices are reflective of an output current max of .5A (model 5E50A) and 1A (model 5E100), respectively. This max current would of course depend on the requirements of all the modules in the project. These also come with guaranteed tolerances of +- 0.1% for the .5A model and +-.15% for the 1A model. These all fit within a small roughly 1X2.5X1 inch package.

This alternative would make the design much simpler. Rather than dealing with all the parts and building the PCB for the first method, this could very easily be integrated into the main microcontroller circuit, being fed simply by just a wall plug. However, they are pretty pricy. Especially if this were to ever try to be implemented in a marketable fashion, there is no way to justify spending over 75 dollars for a power supply that could be implemented with under 25 dollars. While it will definitely be an option to consider in the design phase, depending on the complexity of the rest of the project, it is unlikely that it would be the better option.

Earlier, it was mentioned that a step-down may be needed in some cases. This is because it is much easier to take our regulated 5V DC voltage and step it down to the desired voltage (e.g. 3.3V) than to build a second entire power supply (wall wart, regulator combo). That much is obvious. Of course, a simple method to produce 3.3V from 5V is to put two resistors in series from the 5V line to ground, with the relative resistances being 1.7:3.3. For example, a 170 ohm

resistor in series with a 330 resistor would drop 3.3V between them if they were put in series in that order. However, with this configuration, it would actually be very important to know a constant load being drawn from the stepped down voltage, as this load would be in parallel to the 330 ohm resistor. If it was anything other than much higher than 330 ohms, it would affect the actual resistance seen from the 5V line, and affect the dropped down voltage. Another more feasible option, in many circumstances, is to purchase a DC voltage step-down converter.

There are a couple different types of voltage converters, and basic ones can be implemented very easily, if there is a known input and output voltage. An example of a 5V to 3.3V step-down/step-up is shown below in Figure 9.2.1.1.4. This is the LM3350 from National Semiconductors, and is available from Digi-Key for $2.02 per unit [57]. The advantages of such a converter are the ease of installation, the size (the example below is about .2X.1 inches), and the low cost. The disadvantage is that it is not variable, so the required output voltage must be known in advance.

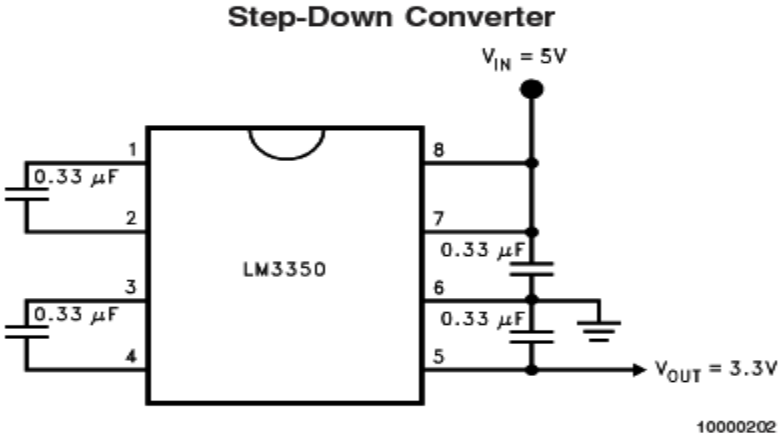


Figure 9.2.1.1.4: The LM3350 5V to 3.3V Step-down converter. Reprinted with permission from Digi-Key.

Another option is a variable output voltage converter. One of these is a 10W adjustable step down switching regulator, DE-SWADJ [58]. This is adjustable with a screw, and could easily be set to the desired output voltage while using a multimeter. This specific model costs $15.00, and shipping is $1.25 internationally. While it is slightly more expensive, it needs no external parts, and would be much easier to implement. The fact that it is adjustable makes it easy to use with changing objectives in an initial design such as this one. This way, if the project's power needs change, the step-down voltage can change with it, without rendering any previously built PCBs and designs worthless. One disadvantage is that it is larger, but still being roughly the size of a quarter in length and width, and maybe half that size tall. Not needing the external parts that the above LM3350 would need makes a big difference in the PCB design.

9.2.1.2 Implementation

For this project, it was decided to use a +12V DC wall wart to provide the power. This is convenient, mainly because of the Op-Amps that require a +12V and -12V biasing. The 5V regulator should perform just as well with the 12V incoming as it would with the 9V. The wall wart used was converted from an older wireless network router wall wart that is rated at 12V DC up to 1A. The part that used to be plugged into the router was split, and the +12V and ground lines were soldered to the PCB to provide for the power rail and ground plane.

It is important, before going further, to know the voltage and current requirements of all of the devices used in the clock. Together, they cannot exceed the ability of the power supply to deliver it. Table 9.2.1.2.1 shows the separate devices, and their power requirements that are known from researching their datasheets.

Device	Voltage Req. (DC)	Current Req. (Active)
Microcontroller	2V – 5V	<10 mA
FM Tuner	4.5V – 5V	8 mA
OLED Screen	4V – 6V	10-115 mA (typ. 40)
PIR Sensor	3V – 5V	<100 uA
Buzzers	4V - 6V	30 mA
Mp3 Decoder	4V-6V	80-100 mA
Clock/Timer	2V - 5.5V	2 mA
ZIGBEE	3.3V – 3.6V	40 mA
Op-Amp	+12V and -12V	
Totals	2.4-3.6, 4-5, -12, 12	250 mA max

Table 9.2.1.2.1: Table of the different components in the GUSU alarm clock, and their voltage and current requirements.

As can be seen in the table above, the minimum amount of voltages required are a +12V and -12V to bias the Op-Amps, a voltage of 3.3V to satisfy the Mp3 decoder and Zigbee components, and a voltage between 4V and 5V to be a sufficient source for the rest of the components. The max current that could be drawn if all of the components were drawing max current at once would be about 250 mA. Of course, that is not possible. For example, if the buzzer is drawing current, then the FM Tuner and Mp3 decoder would not be, and vice versa. Regardless, it is best to plan on a higher max current draw than is possible so that there are no problems. In that regard, it is important to make sure that all components involved in the power supply are rated to handle a current of 500 mA flowing through them. The above table can also be used to construct a simple block diagram of the power supply system, which is shown in Figure 9.2.1.2.2.

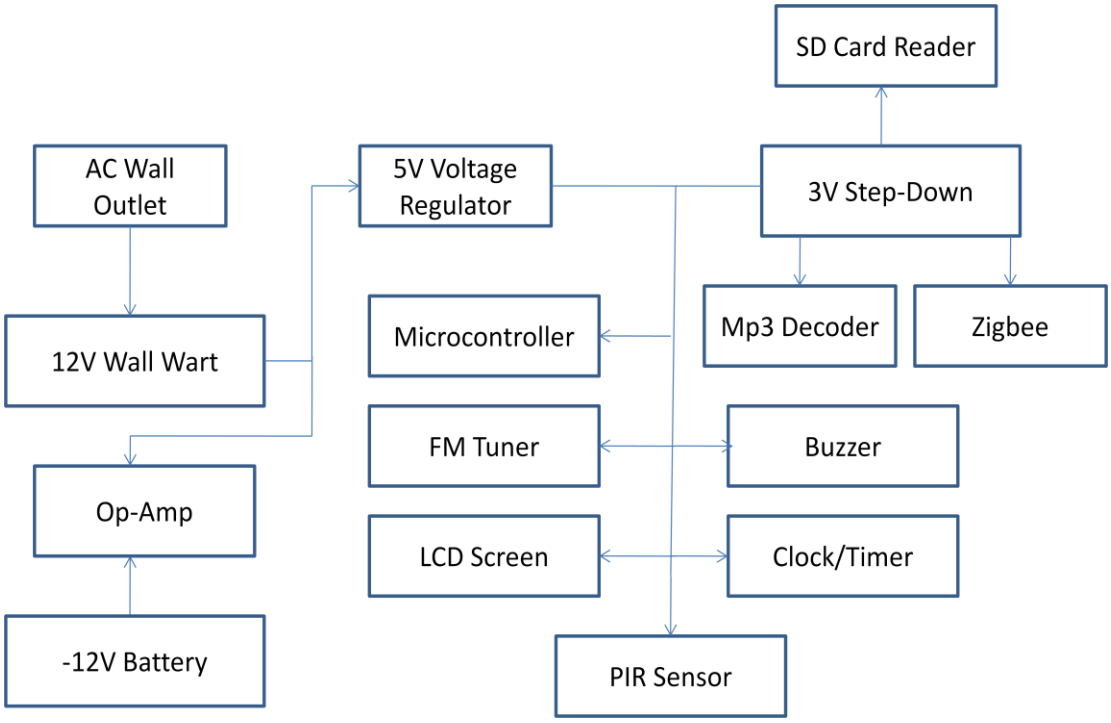


Figure 9.2.1.2.2: Block Diagram of the Power Supply System.

The +12V and -12V are taken care of through the use of the 12V wall wart and the DC/DC converter (discussed in Section 4.2.1.2: Audio Amplification). The 12V power rail is just a thin trace over to the Op-Amp from the larger trace to the voltage regulator on the PCB. The voltage regulator used is the LM7805CT-ND 5V 1A regulator, manufactured by Fairchild Semiconductors, and purchased from Digi-Key for $0.45 each. This regulator takes the input 12V and outputs a steady 5V (According to specs, 4.8V to 5.2V, which should be good for all the components). This voltage regulator is implemented with the circuit below in figure 9.2.1.2.3. The two capacitors help to stabilize the DC input and output in case of short power drops (for drops in power on the order of 10 to 100 ms). The LED, as explained in the research section (9.2.1.1), is positioned with the resistor so that only 15 mA should flow through it. This is to prevent the excess of current from damaging the component.

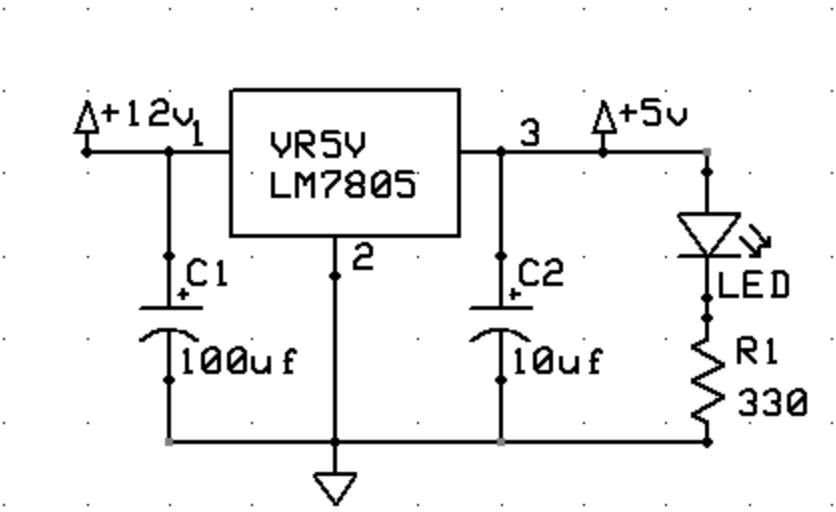


Figure 9.2.1.2.3: The 5V voltage regulator.
Schematic created using ExpressSCH.

This 5V line also needed to be 'stepped down' to a value of 3.3V. Another voltage regulator (LM11171) was used to drop it to 3.3V. PCB implementation will be discussed in Chapter 10.

9.2.1.3 Testing

The power supply was tested completely. Each component's power voltages and currents were measured using a multi-meter on the final PCB, and all were within specs of the devices.

9.2.2 Battery Backup

Battery backup is considered to be an integral part to the Get-Up Stay-Up alarm clock system. This is because if the user decided that he/she would like to sleep through the noise, the only thing the user would have to do is remove the power plug from the wall. That would have made the entire project pointless. A worthwhile battery backup would not need to last long; with the noise planned on coming out of it, less than 5 minutes should be needed to fully wake any sleeper. It is just important that the user cannot disable it easily, so the battery backup would need to be encased with screws needed to remove the batteries. The backup would also be able to keep the clock time set during short power outages. The specifications for the device are that it is able to provide uninterrupted power for at least 8 hours (the average power outage lasts about 4 hours) when unplugged from the wall with a fresh battery, that it does not drain the battery when there is current flowing from the wall outlet, and that there is minimal to no lag during the switch, so the devices do not lose information.

9.2.2.1 Research

An easy way to incorporate battery power is to stick commonly available batteries prior to the 5V regulator. While this is a waste in a way, only using 5V of the batteries outputting voltage level, it is a simple way to incorporate the battery backup. The wastefulness likely would not impact the user, as the battery will almost never be used. This is not for an emergency radio that could be used in the event of hurricane-like power outages, it is meant to last long enough to wake the user if the user unplugged the clock from the wall and survive short power outages. Eight AA batteries could be placed in series to come up to a total voltage of 12V DC. This voltage could have differed of course, based on the needs of the design. According to Techlib.com, the average AA battery lasts about 2000mAhrs [59]. So even if the clock used a total of 250mA, which is an extremely high estimate, the battery backup would last over 8 hours. In fact, 2 or more sets of the AA batteries could be placed in parallel to increase this estimate. But with just one set, it would last long enough for the user to completely wake up after unplugging the alarm clock as many times as necessary to break them of that habit. It would also hold the power steady during small power outages.

One important thing to consider is that the batteries should not be draining while the alarm clock is plugged in. This could be accomplished easily with one major constraint: whatever the final power supply voltage is prior to the regulator, the voltage supplied by the batteries must be less. If this is the case, a simple diode placed heading from the battery supply to the voltage from the wall wart would keep the current from exiting the battery supply (there would have to be roughly a .7V drop between the two for current to flow. In this case, if the input voltage dropped significantly (at least .7V) below the battery supply level, the battery current would kick in. It would be extremely important that the battery supply was lower than the voltage coming from the wall wart/power brick, as if it were higher, the current would flow through the diode anyways. It could be accomplished by simply stacking as many AA 1.5V batteries as necessary without going too high. It is important that it is nearly 12V however, so that the 5V regulator has enough voltage to account for the drop it needs, and the Op-Amp can be biased, so it makes sense to go to 12V as long as the wall wart is above that level.

9.2.2.1 Implementation

The entire battery backup implementation was simple enough. It just required 8 AA batteries in series, or 1 12V battery (A23 model, by Duracell), followed by a diode. With a wall wart with a voltage greater than or equal to 12V, the current will never drain from the batteries except when the main power supply is unplugged. This is because of the .7V drop on the diode that is necessary in order for current to flow from the battery backup. The line coming out of the diode connects to the line from the wall wart to the DC 5V regulator. A schematic of this can be seen in figure 9.2.2.1.1.

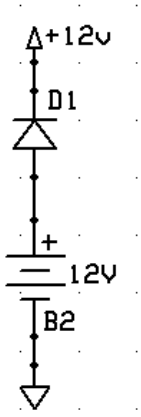


Figure 9.2.2.1.1: Schematic of the battery backup system, made with ExpressSch. The DC voltage is actually the 8 AA batteries in series (or 1 12V battery), in a small case made to hold them as compactly as possible.

The battery backup does not take any space on the PCB, as there is a premium for that space (the larger the board, the higher the cost). Instead, the battery backup is attached to the case with screws, with leads going from either end of the battery and being soldered into two holes in the PCB. A small plastic casing was purchased at a local Radio Shack for $2.00 to hold the batteries, and this was screwed into the casing.

With the backup battery, the group also wanted to know if the batteries needed replacing. Due to the audio restraints involving the Op-Amp, the clock requires at least 10-11V for positive and negative biasing. So an LED was used to show that the battery needed replacing when the battery voltage level dropped below this amount. This LED was in series with a 133 Ohm resistor, so that when the battery voltage dropped to about 10-11V, the LED would turn on, indicating to the user that the batteries needed replacement. This is shown below in Figure 9.2.2.1.2.

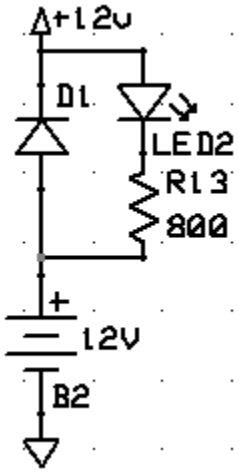


Figure 9.2.2.1.2: Schematic of the Low Battery LED, made with ExpressSCH.

9.2.2.2 Testing

The backup battery was tested extensively. First, the device was powered on using the wall wart. Next, the battery backup was connected. The current was measured through it with a multimeter the entire time. At first, a few mA did pass through the batteries, although after some use as the voltage fell below 13.25 V, it no longer drained any current. After the wall wart was unplugged, there was no data loss, and with all devices powered that would be at any given time, the drain was approximately 230 mA. Next, the device was run only with the microcontroller, OLED, and clock active. The device was checked on every hour, and the battery replacement LED went on after the 23rd hour. At this point, the batteries still provided enough voltage to power the device, but not enough for the Op-Amp, causing any audio signals to saturate.

10.0 Software

10.0.1 Motivation

In order to bring all of the systems and functions of the GuSu alarm system together in an automated fashion, a form of logic must be built in to the system itself. An incredibly complex artificial intelligence could serve to expand functionality and introduce auto calibration and so on. But this is highly unnecessary as the requirements and design of the overall user interface and GuSu system provide ample flexibility for user preference and system performance. The following sections discuss alternatives and software choices and then go on to explicitly describe the software that will be written for the GuSu system and how it will behave.

10.1 Software Research

10.1.1 Alternatives

The GuSu system architecture could be controlled and run solely by hardware using binary logic. Binary clocks, abstracted Boolean logic, transistors to flip on and off the various alarm systems and other controls could theoretically accomplish anything software would do. However, as possible as this is, it is highly implausible and would greatly increase the time for design, construction, and debug of the system. User control would become excessively complex, and as college students the team does not have access to materials and equipment for making miniature electronics, and this if the system was built to run on hardware only its size and weight would increase beyond the specifications chosen for the GuSu unit's housing. Similar discussions involved implementing the internal clock using binary logic gates but the advantages of ordering a component that is pre-made and tested far outweighed the disadvantages of going ahead with making one from scratch. Thus all of the GuSu alarm system's functions and sub systems will be controlled through software run on the central

microprocessor.

10.1.2 Programming Languages

The microcontrollers investigated to run the GuSu device interpret C, C++, and the descriptive programming language Arduino. Since C++ has all the abilities of C and more, it of course would be very advantageous to use over C. Arduino, which is C-like in syntax, has the advantage of being structured and created as a Processing/Wiring language, reducing the amount of abstraction between physical microcontroller hardware and software written to control it. While C++ is an excellent language for higher level systems and complex software packages, the GuSu alarm system in the grand scale of things is a rather "simple" system overall and would benefit more from the use of Arduino than C++. To further this point the two languages are compared below in the following table.

Feature	**C++**	**Arduino**
Compiler/Developer Environment Available	Visual Studio, Xcode, Bloodshed, Dev-C++	Arduino 0015
Programming Language Support	All C/C++ libraries	All AVR-g++ constructs
Open Source Projects?	Yes	Yes
Operating System Support	Windows/OS X/Linux	Windows/OS X/Linux

Table 10.2.2.1 Comparison of Programming Languages

The reasons for choosing an Atmel microcontroller are fully discussed in section 3.0, in addition there are several reasons Arduino is a good platform from a software perspective. Full operating system support alone makes the IDE very attractive as the team members regularly use Windows XP, Windows Vista, and Mac OS X, and thus team efforts towards programming and debugging will be easier compared to a development platform such as Xilinx and VHDL which are primarily supported on Windows. A minor factor is graphical user interface of the development software, which Xilinx and most C++ development suites sacrifice simplicity to provide a flexible and robust environment. The Arduino IDE is very simple and straightforward in comparison, and is pictured below in figure 10.1.2.1. A significant option that comes with Arduino is its ability to be extended using C++ libraries, meaning that if it is found a certain C++ function or library would enhance the software it can be included as needed. Much like C/C++ Arduino can also be compiled using a make file and command prompt, adding yet another degree of flexibility. As mentioned earlier, the overall function of the GuSu unit is relatively simple, and implementing the software should not require strict object oriented or higher level programming that a simulation or complex system control would. Therefore the software shall be structured using specialized functions, variables, and parameters to run all functional systems,

actions, and menus.

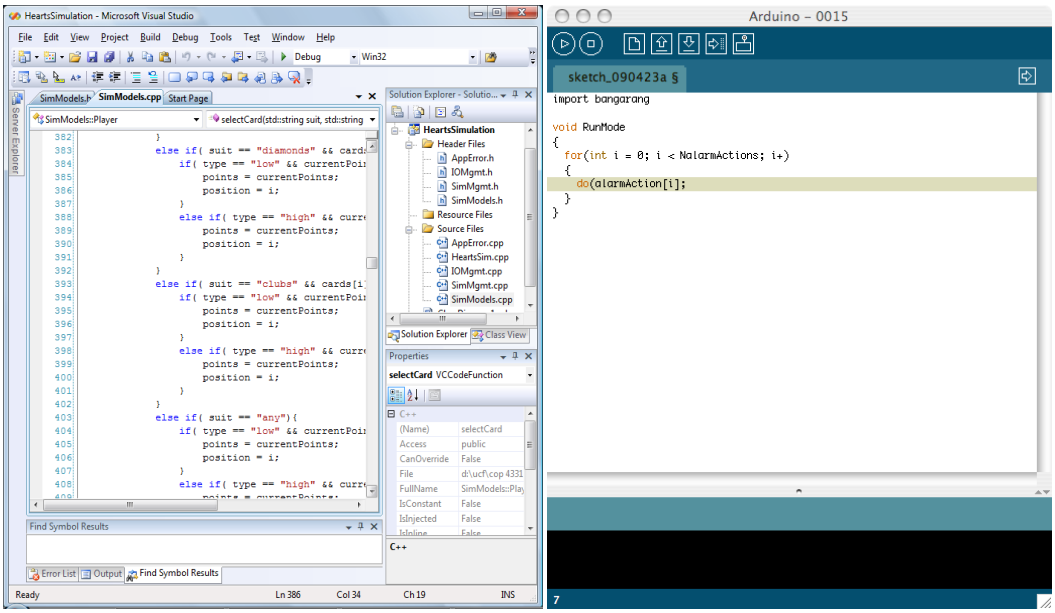


Figure 10.1.2.1: Side by side comparison of IDEs

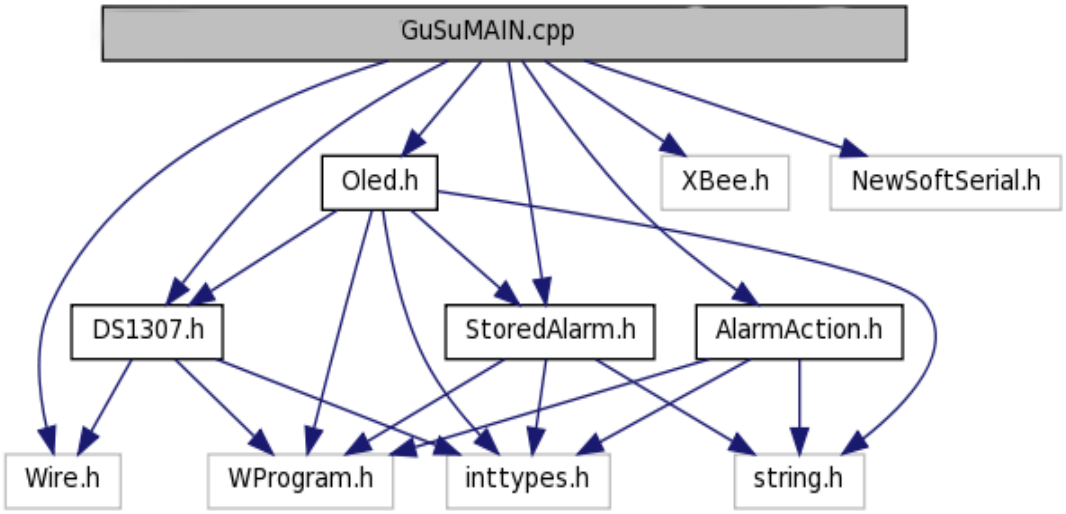
10.2 Software Implementation

10.2.1 General Configuration

Two main functions call and encapsulate all other functions; **SetMode** and **RunMode**. These are the only two modes the GuSu unit can be in once the system completes initialization, and as their names suggest, are the modes where the use changes settings and where the GuSu alarm system is running, that is checking the time, checking for user presence in the sleeping area, and at alarm time if the user is present performing the user's preset alarm routines. Most alarm clocks when first turned on have default settings of midnight alarm and current time, and the alarm activated. This could be somewhat "dangerous" in a loose sense of the word given that if the GuSu is in **RunMode** and the clock returns the alarm time it will not let the user easily enter **SetMode** to silence it, and thus will force the user out of bed unless they point the infrared sensor away or find a similar fashion of becoming undetectable. But even escaping detection the user still cannot enter **SetMode** until either the alarm time span has passed or they hold the correct button for the chosen emergency silence time, currently chosen to be three minutes. To avoid this scenario entirely, however unlikely, the GuSu unit's startup routine does the following; set clock to noon, set clock alarm to null, set all alarm and action durations to five minutes, and finally enter **SetMode**, displaying the setting mode GUI menus on the OLED screen. To further ensure a correct initialization and setup for the first run the user is forced to either choose a setting for or deactivate each available alarm action and the

alarm time must be set.

A subroutine of the **SetMode** is included that allows the user to test run the alarm actions following the routine they have specified, which can be stopped early, and a mode for testing the sensor positioning by signaling when it detects their presence using the on board alarm buzzer. Once the user has made their selections in **SetMode**, they are allowed to enter **RunMode** and the GUI on the OLED screen will switch to the running display as described in section 5.4. Before discussing the functions and modes in depth the global variables are named and defined in figure 10.2.1., followed by enumerations used, shown in figure 10.2.1.3. Explicit pin numbering will also be saved as global variables for easy access and changing, and are laid out explicitly in table 3.3.1. Below the dependency graph is shown in figure 10.2.1.1 for reference followed by in depth description of variables, enumerations, and functions.



10.2.1.1 Dependency Graph

- int **mp3PowerPIN** = 6
- int **fmPIN** = 1
- int **SoftBuzzerPIN** = 25
- int **LoudBuzzerPIN** = 24
- int **PressureSensorPIN** = 0
- int **upPIN** = 26
- int **downPIN** = 27
- int **leftPIN** = 28
- int **rightPIN** = 29
- int **enterPIN** = 30
- menu_key **nextMenu** = SETUPmenu
- action_key **actionToSet** = MP3key
- boolean **actionIsRunning** [5] = { false, false, false, false, false }
- char **weekday_strings** [7][6]
    - An array of strings for displaying days of the week on setting screens.
- char **month_strings** [12][6]
    - An array of strings for displaying months of the year on setting screens.
- StoredAlarm **alarmTimes** [7]
    - An array of seven StoredAlarm objects used to store the user's seven week day alarm times.
- StoredAlarm **nextAlarm**
    - StoredAlarm variable used when checking for alarm time and displaying for the user what the upcoming alarm is.
- char **string_nextAlarm** [20]
    - string generated for displaying the upcoming alarm time
- AlarmAction **myActions** [TOTAL_ACTIONS]
    - Array for storing alarm actions, TOTAL_ACTIONS being a defined value for easy addition/subtraction of alarm actions.
- boolean **XBEE_use** = 0
    - value used as a boolean and set by the user whether they want to use the wireless devices in range
- byte **XBEE_delay** = 0
    - value set by the user determining how many minutes after alarm time to send the wireless activation signal
- boolean **XBEE_connected** = 0
    - value used to keep track of whether any wireless devices in range are connected
- boolean **ON_BATTERY**
    - boolean for deciding how to take action if wall power source is no long recieveing power all behaviors change based on power status
- int **SENSORread** = 0
    - variable set whenever checking the sensor system
- float **originPressure** = 0
    - analog value set at startup representing pressure read in the bedding area when it is empty
- float **pSENSITIVITY** = 1.001
- byte **alarmTimeSpan** = 30
    - span of time following alarm time in which to continue sensing for the user in bed and sound alarm
- boolean **weekendEasyOff** = true
    - boolean set by user as to whether to allow silencing of the alarm during the weekend or not

- long **lastDebounceTime** = 0
    - value tracking time after previous debounce, preventing multiple pushbutton reads dto the sample speed being faster than human factor
- long **debounceDelay** = 100 milliseconds to delay debouncing
- pushbutton **lastPUSH** = NONE globally stored value of the last pushbutton read received
- int **UPpressed** = HIGH current reading from the UP pushbutton wire
- int **DOWNpressed** = HIGH current reading from the DOWN pushbutton wire
- int **LEFTpressed** = HIGH current reading from the LEFT pushbutton wire
- int **RIGHTpressed** = HIGH current reading from the RIGHT pushbutton wire
- int **ENTERpressed** = HIGH current reading from the ENTER pushbutton wire
- int **UPold** = LOW previous reading from the UP pushbutton wire
- int **DOWNold** = LOW previous reading from the DOWN pushbutton wire
- int **LEFTold** = LOW previous reading from the LEFT pushbutton wire
- int **RIGHTold** = LOW previous reading from the RIGHT pushbutton wire
- int **ENTERold** = LOW previous reading from the ENTER pushbutton wire
- byte **endHour** = 0
    - the hour value denoting the end of the alarm time span, calculated by comparing alarm time span setting with next alarm
- byte **endMinute** = 0
    - the minute value denoting the end of the alarm time span, calculated by comparing alarm time span setting with next alarm
- byte **midHour** = 0
    - the hour value denoting the middle of the alarm time span, calculated by comparing end hour with next alarm
- byte **midMinute** = 0
    - the minute value denoting the middle of the alarm time span, calculated by comparing end minute with next alarm
- boolean **useBackup** = 0
    - value for storing previously set value for whether or not to use the related alarm action, this allows the user to press LEFT and restore the previous value
- byte **delayBackup** = 0
    - value for storing previously set value for how long to delay the related alarm action, this allows the user to press LEFT and restore the previous value
- byte **durationBackup** = 0
    - value for storing previously set value for how many minutes the related alarm action will occur, this allows the user to press LEFT and restore the previous value

Figure 10.2.1.1: Global Variable Definitions

- enum **menu_key** {
  LEAVEmenu = 0, SETUPmenu = 1, CLOCKmenu = 20, DATEmenu = 21,
  ALARMmenu = 30, ACTIONmenu = 40, MODULEmenu = 41, XBEEmenu = 44,
  SYNCmenu = 441, SYSTEMmenu = 50, BEHAVIORmenu = 51, GuSuSYNCmenu = 52,
  SCREENmenu = 53
  }
    - Enumerated list of key values for each setting menu. Keywords are used to determine which menu should be called next by the **masterMenuCommand**() function. 0 Exits out to **RUNmode**, 1 calls the overall **SETmode** menu, while other values are run by a hierarchy. Originally the setup menus were coded to act as a tree branching menu system, with menus calling other menus. However, memory constraints forced us to do this virtually. While to the user the menus appear and act exactly the same as before,

loop() now only calls **masterMenuCommand**(), which decides based on the value of **nextMenu** what menu to call next, or whether to call **RUNmode**. This slightly complicates the code, and can make changes a bit more difficult, but achieves the user end goals while leaving plenty of memory free to avoid overflowing the stack and crashing the system.

- enum **action_key** {
  MP3key = 0, FMkey = 1, SOFTkey = 2, LOUDkey = 3,
  SIRENkey = 23, NOaction = 10
  }
    - Enumerations for possible action menus to call. Similar to **menu_key**, this is another level that works combined with the **menu_key** if the user wishes to go into an action setting menu. When the user is in the **ActionMenu** and pushes RIGHT or ENTER both **nextMenu** and **actionToSet** values are set and looked at by **masterMenuCommand** to decide which **AlarmAction** to pass to the **ModuleSet** function.
- enum **weekday** {
  Sunday = 1, Monday = 2, Tuesday = 3, Wednesday = 4,
  Thursday = 5, Friday = 6, Saturday = 7
  }
    - Enumerated days of the week.
- enum **month** {
  JANUARY = 1, FEBUARY = 2, MARCH = 3, APRIL = 4,
  MAY = 5, JUNE = 6, JULY = 7, AUGUST = 8,
  SEPTEMBER = 9, OCTOBER = 10, NOVEMBER = 11, DECEMBER = 12
  }
    - Enumerated months of the year.
- enum **pushbutton** {
  NONE = 0, UP = 1, DOWN = 2, LEFT = 3,
  RIGHT = 4, ENTER = 5
  }
    - Enumerations for possible pushbutton values. These values and words are used to make the code more readable and reduce complexity of debugging pushbutton reads

Figure 10.2.1.2: Enumeration Definitions

The Zigbee module does not need a duration variable since devices that connect through Zigbee are preprogrammed internally to perform their own actions; they remain idle until a signal is received from the GuSu unit.

10.2.2 Overall Behavior

The **setup()** function first performs system initialization and object creation before moving to loop() which clears the screen and calls **masterMenuCommand**, linking the user to subordinate functions which handle changing settings for the GuSu alarm. These functions are; **ClockSet**, **AlarmSet**, **ModuleSet**, and **SystemSet**. Each of these Set functions is entered by selection of the user in the main **SetMode** menu. All Set functions are structured to loop until the LEFT button signal is received, and will otherwise follow the user's navigation to select a sub function, each of which handle adjusting the variables associated with the device of the Set function. Exiting subordinate functions is handled the same

way, detecting a LEFT signal, and also loops until that signal is received. All set functions behave in the following way; start with selection set to the highest option, loop until LEFT signal received, UP and DOWN signals will cause the selection to be incremented or decremented respectively, and a RIGHT signal causes the program to enter the selected subordinate set function. Inside subordinate set functions UP and DOWN increment and decrement the related variable until a CENTER signal is received, causing the program to exit the loop and return to the main module Set function.

ClockSet acts differently from the other functions in that along with exiting on a LEFT signal, the input time is also pushed out to the internal clock. This is done because there is no guarantee the user will finish changing settings in less than a minute of choosing the clock time. It would be possible to track how much time elapses between choosing the clock time and exiting **SetMode** but this is adds unnecessary complexity and wastes resources. The **AlarmSet** function also uses explicit code that converts the user's abstract selections of 7-day, weekday/weekend, and every day for the alarm timing modes. In the case of 7-day the user's chosen times are saved to the **alarmTimes** array to the respective slot. For weekday/weekend the first five time slots are filled with the chosen weekday alarm times, while the last two slots are saved with the chosen weekend alarm time. If every day is selected then one time is saved to all spaces in the array. **ModuleSet** is the backbone of **SetMode** and is responsible for more of the GuSu's system's flexibility, which leads to this function being implemented in an object oriented manner to facilitate expandability. Whenever the GuSu alarm is in **RunMode** it only cares about three things when it comes to alarm actions, with the exception of Xbee devices; whether the action is to be taken, how long the action will last, and how long of a delay after alarm time the action is to occur. The MP3 module, FM tuner, soft buzzer, and loud buzzer all have global variables to store the needed information for the three mentioned concerns, allowing the variables to be passed into ModuleSet and manipulated as the user wishes. This way any additional actions to be implemented in the future can easily be added in by creating the three needed global variables and handled just as smoothly when they are passed into **ModuleSet**. The **XbeeSet** function requires a **XBEE_test** function which makes an attempt at connecting with any Zigbee devices in range and informs the user of what it successfully connected to.

During alarm time spans power is sent to the sensor system and the output received is interpreted. Based on the current time and the time spans chosen for the various alarm actions the software chooses which action to take if the user is detected with the exception of Zigbee actions. For example given the scenario of the user setting the alarm time for the current day for 6 a.m., the FM tuner to play for fifteen minutes, followed by MP3 files for thirty minutes, and Zigbee devices to occur last with the wake up action turned off, the FM will go silent once the user rises from bed, if the user is detected in bed again at any time between 6:15 a.m. and 6:45 a.m. MP3 files will be played, and at 6:45 a.m. the Zigbee devices that successfully connect will be activated. At the start of each **RunMode** loop the

current time will be requested from the clock and updated on the OLED screen, the upcoming alarm time is displayed along with the current date. If the user has chosen to use the keychain tracker device a connection is made with it once the user is no longer detected in the bed. The time the connection succeeds is stored. Once the connection is lost the current time is compared to the time stored earlier and the difference is stored and averaged with previous values, along with the number of times compared being incremented by one. These values are used to estimate the time it takes the user to leave their home once they have left the bed and after a certain number of values being stored and averaged the option for "most sleep" will be available where the user can choose what time they wish to leave rather than what time they wish to wake up, and the GuSu software decides what time they need to be awoken based on that time and the time it takes them to leave.

RunMode continues looping until a CENTER signal is detected, which waits for the signal to continue over a time depending on if the current time falls within the alarm time span, if that wait time is reached **SetMode** is called. The subordinate function of **RunMode, PlayMode**, is entered if the UP signal is received over five seconds. This function allows use of the GuSu system as an FM radio or MP3 player, and is overridden if the alarm time is reached and the user is detected in bed. Overriding **PlayMode** is easily handled as when the alarm time saved to the clock is reached, the clock device chosen for the GuSu system automatically sends an interrupt signal. Figure 10.3.1.2 illustrates the overall flow of the GuSu system beginning at first turn on and running indefinitely.

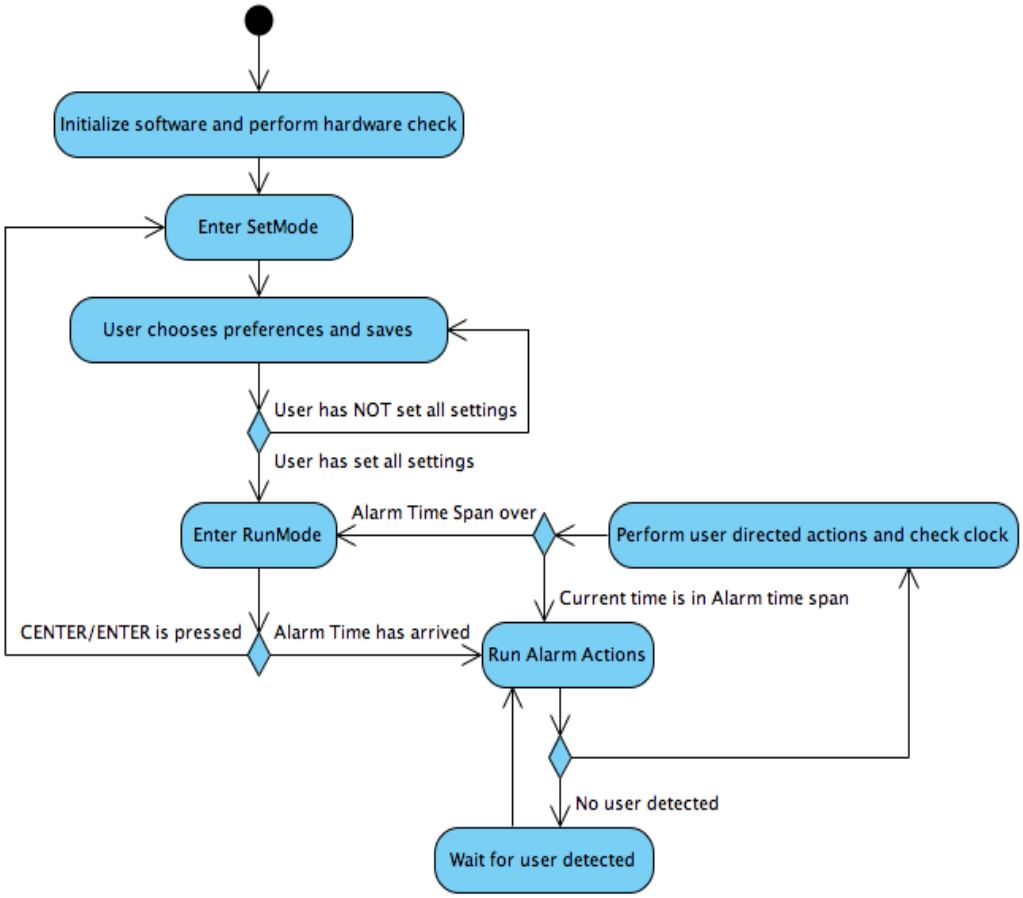

Initialize software and perform hardware check
Enter SetMode
User chooses preferences and saves
User has NOT set all settings
User has set all settings
Enter RunMode
Alarm Time Span over
Perform user directed actions and check clock
Current time is in Alarm time span
CENTER/ENTER is pressed
Alarm Time has arrived
Run Alarm Actions
No user detected
Wait for user detected

Figure 10.3.1.2: Overall Activity Diagram

10.2.3 Functions

10.2.3.1 RunMode Functions

The **RunMode** function itself acts as a loop and branch that continually checks the time and listens for user input. Depending on the current time, alarm time span, and user interaction **RunMode** will enter subordinate functions or call on **SetMode**. **RunMode**'s subordinate functions are laid out in name, purpose, and behavior here. All alarm action function exit and control options act similarly depending on how the function was entered. If the function was called because alarm time was reached then the user can only exit by holding down the CENTER/ENTER key and entering **SetMode**. If the function was called by **actionTest** the user can interrupt the function without delay and return back to **SetMode**. All alarm action functions also have a method internally that makes them continue running until the desired time span has elapsed. These functions must also check for user input so they can be interrupted by user interactions. All action functions will also be passed a parameter integer which informs them of how they were called.

10.2.3.2 MP3 Handling

Play_MP3

This function is called in one of three ways; alarm time is reached while the GuSu system is in **RunMode**, **TestMode** is called while the user is changing settings, or **PlayMode** is entered during runtime. This function handles sending data requests to the on board Secure Disk reader, and passing the data stream on to the MP3 decoder chip, and also controlling the chip. The function also sets the on board multiplexers control bits accordingly to direct power to the MP3 decoder chip and Secure Disk reader, along with directing the audio lines to accept only signal from routed from the MP3 decoder to the GuSu system's speakers. Play_MP3 differs from other alarm actions in that if the function was entered from **RunMode**.

Stop_MP3

Function called when MP3 audio is to be stopped. This may be at the end of alarm action time, because the user has left the bed, or the user is stopping **actionTest.** The function sends a command out to the VMUSIC2 module, and checks if it is still receiving data over the serial line. If so it will send the stop command again, repeating its check and send process until the MP3 audio stream stops.

10.2.3.3 FM Handling

Play_FM

Similar to Play_MP3, Play_FM must set multiplexer controls to route power to and audio from the FM tuner. The FM tuner itself is relatively self contained and therefore does not require much interaction from the microcontroller directly. The FM station tuning is handled externally to the microcontroller and so no LCD output or passing of control information needs to be passed on to the tuner by the microcontroller.

Stop_FM

Called to shut down the FM tuner, this function merely sets a digial pin powering the fm tuner to LOW.

10.2.3.4 Buzzer Handling

Sound_Buzzer

Two multiplexers are set by this function, one that passes power to the buzzer module, and one that selects either the loud or soft buzzer depending on what

user preference has been set. If time allows during the build and test phase during the following semester an attempt will be made at adding the capability to slowly increase the volume of the loud buzzer. This gives the user the option for a rising alarm sound that for some can be a gentler way to wake up rather than sudden or loud noises. This improves the GuSu system's ability to accomplish its overall goal of waking the user properly, which encourages the user to arise from bed and stay out of bed rather than simply react to a disturbance and return to slumber.

Stop_Buzzer

Called for buzzer shutoff, it accomplishes this by setting the pins powering the buzzers to LOW. Since the method is simple It is called for both the soft and loud buzzer.

10.2.3.5 XBEE Handling

XBEE_cycle

This function is called most often as it must act as the middleman between the GuSu system and all Zigbee devices in range. On startup a signal must be sent to the Zigbee module to create a network and start accepting connections from nearby devices. The XBEE_cycle function sends activation signals to Zigbee devices, accept and examine information returned from the Zigbee module, log disconnection times, and provide the necessary data for the microcontroller to display during **SetMode** and **RunMode** what devices have succeeded in connecting with the GuSu system. Disconnects, especially with the tracking device used for checking when the user has left their home, must also be reported to the GuSu system and handled accordingly. The function accepts a Boolean value, and either sends a turn on or turn off signal accordingly, the signal is sent three times every time the function is called to ensure a successful activate or deactivate.

10.2.3.6 Run_Alarm

The above functions are all called by this function, which is entered when the alarm time is reached and the GuSu system is in **RunMode**. Upon entering this method a check is made to the alarmActionOrder array, and the number given is used to decide which Boolean to check to see if that action was enabled by the user. If the action is enabled the related action function is called and executed until passing control back to the Run_Alarm function. Control is also given back if the user is no longer detected in the bed. If this occurs Run_Alarm awaits either sensor signals to start alarm actions again, or user input to enter **SetMode** if the user holds down the CENTER/ENTER pushbutton long enough.

10.2.3.7 SetMode Functions

All SetMode functions behave as menus and work to emulate a tree branching menu system. They constantly check for pushbutton input while controlling the OLED screen to display what information is needed and changes made by the user.

10.2.3.8 masterMenuCommand

This function acts as the master control for moving between menus. As each menu exits it sets **nextMenu** to the corresponding enumerated value before passing control back to this function. Originally menus called other menus but due to memory constraints this was implemented to reduce memory usage while the user is changing settings on the GuSu system. The function loops between setting menus until exit is called within **SETmode** (here designated by **SETUPmenu** enum value). Once exit is called, **doubleCheckSettings**() is called. If it returns TRUE then **RUNmode** is called. When **RUNmode** is exited **SETmode** is called next.

10.2.3.9 SystemSet

Menu for changing overall system related settings. This menu gives the user access to the behavior setting menu, Wireless setting menu, and GuSu setting menu. It was planned to also have a menu for "Screen" settings that would allow the user to set what time span the clock display should be dimmed after sundown, and give the user some color options, but project timing did not allow for these options to be implemented.

10.2.3.10 GuSuSet

GuSUSet is a menu for setting GuSu specific settings. More options were planned for this menu, such as wirelessly syncing two GuSu systems, but as of project completion this menu only contains the operation for re-calibrating the systems pressure sensing.

10.2.3.11 ActionSet

This setting function deals with configuring alarm actions. All actions at a minimum have three options, Use, Delay, and Duration. Currently the system comes equipped with an MP3 audio interface through user storage media, an FM radio tuner, a loud/siren buzzer, and a softer more common alarm buzzer. In addition to configuring the behavior of these audio alarm functions, the overall behavior of the system during alarm time can be set by entering the **BehaviorSet** function from this menu, discussed in its own section.

10.2.3.12 BehaviorSet

Function for displaying and handling the setting menu for overall system alarm time behavior. Here the user sets the time span after alarm time in which to

continue sensing for their presence in bed and take action to arouse them, and whether they want to be able to silence the alarm on weekends.

10.2.3.13 ClockSet/DateSet

Function for displaying and handling user setting the current clock time. This menu function displays and allows changing of the current date, weekday, hour, minute, and whether it is AM or PM. For setting the date the **DateSet()** function is called as a separate branch due to the limitations of a maximum of four items displayed at once per menu. **DateSet** is a menu function for the displaying and handling of setting the current day of the month, month, year, and weekday.

10.2.3.14 doubleCheckDate

Function for checking for invalid date settings. This function gets passed the user's selection for date and month and checks for invalid entries, such as 31st of February, in which case it will return false. If all values are valid, or if the user has set a month that does have 31 days, and so is not checked here, true is returned. It is unnecessary to check every month or the value because the date setting menu automatically loops from 31 to 1 within the

10.2.3.15 AlarmSet

Menu function for the displaying and handling of configuring the alarm times for all seven weekdays. This functions structure differs slightly in that each time the user changes the weekday displayed they are editing that day's alarm time rather than editing what day of the week the alarm occurs.

10.2.3.16 ModuleSet

Generic functions are used for adjusting settings for each alarm action excluding Xbee/Wireless. All alarm time actions have a boolean "use" variable, a chosen number of minutes after the alarm time in which to act, and how long once the action has begun to continue the action. Delays have been hardcoded to a minimum of 0 and a maximum of 30, durations have been hard coded to a minimum of 1 and maximum of 30. This newer function gets passed a pointer to an **AlarmAction** object stored in the **myActions** array. The code has been made much cleaner, shorter, and easier to read by this, along with reducing memory usage slightly. Usage speed has not been noticeably affected.

10.2.3.17 XbeeSet

XbeeSet is a menu function for the displaying and handling of the wireless settings. This menu was hardcoded due to the need for syncing functionality, displaying the current wireless status (connected or not), and there being no need for a duration value for the Xbee module since it merely sends out an activate signal.

10.3 Software Testing

All software requires thorough unit testing to guarantee integrity and an implementation free of both runtime and logical errors. Unit testing has been written into and for all functions, and proof of concept versions were written in C/C++ for external logic testing before attempting to make the software work directly with the microcontroller. All GUI menus were tested to double check menu handling and data changes were being handled correctly in both change/save and display. As project completion neared steps were taken to reduce memory usage, mainly changing the code to emulate rather than truly implement a tree branching menu system. This was due to menu functions calling menu functions, which would exponentially increase memory usage. The solution to this problem was to create the **masterMenuCommand** function which handles calling all menus based on what menu is requested by the previous menu. **masterMenuCommand** itself has no variables and so does not use stack memory, and also only allows one menu to be operating in menu at a time.

11.0 Printed Circuit Board

In order to attach all of the different modules and devices in this alarm clock together, it will be necessary to use a PCB (Printed Circuit Board). While all of the members of the group only have experience working with breadboards, it is not feasible to use one of these in the clock. They are large, bulky, and most importantly, do not allow the permanent soldering of the different devices. There are, of course, multiple methods of going about using PCBs in this project, however.

11.1 Research

The easiest method is often to outsource the actual creation of the PCB itself. This can be done through one of many companies online, all of which charge different prices for different services, but do roughly the same thing. They take a PCB schematic, use it to build a PCB, and return the PCB to the customer within a few days to a week. These PCB schematics are not the same as regular schematics, but that will be discussed later. The obvious advantages to this method of PCB development are the time and mistake savings. In other words, none of the group members have experience using a milling machine (the machine that can create the boards); it will take a lot of time for a couple of the members to learn the process of creating the board. There is also the time involved with getting certified to use the milling machine provided by UCF to the students, and while this time also helps to familiarize the users with the machine, it is not enough to make them truly competent users. This is also the cause of another time-drainer: mistakes. If any mistakes are made, it would render the board worthless and involve the purchase of another blank board.

It would likely still be worthwhile to become certified, however. There can be several reasons for this, but most importantly, it gives options in case there are

mistakes in the design. If a design has a mistake in it, where a trace was made that shouldn't have been, or vice versa, it is possible that it could be fixed by using the milling machine at UCF rather than purchase another board. As will be seen below, while the boards are not ridiculously priced, it would get rather expensive to keep repurchasing the boards because of simple errors.

While the common companies available to produce PCBs do charge a premium to have them create the board for you, they are generally guaranteed to be done right. There are many different companies around, so each will be looked at to determine the feasibility of using that company. This applies to both the company manufacturing the board, and the company whose software will be used to create the PCB schematic. These PCB schematics are known as 'Gerber files' [53]. These Gerber files are actually a collection of seven required files: Top Copper Layer (GTL), Top Soldermask Layer (GTS), Top Silkscreen Layer (GTO), Bottom Copper Layer (GBL), Bottom Soldermask Layer (GBS), Bottom Silkscreen Layer (GBO), and a Drill File [53]. The three-letter names in parenthesis in the previous sentence refer to the file extension of each file, respectively.

The first fabrication company that will be looked into is PCB123. A quick estimate of the needs of the group's board size would be about 8 X 10 inches, so that estimate will be used as a pricing estimate for the different companies as of now. Of course, when the final PCB schematic is completed, the choice of company could be changed if the final dimensions are significantly different, and would change the choice of PCB producer. As mentioned earlier, regardless of the software chosen, the hardware development uses the same files. Because it is standardized, any company's software can be used, and the files sent to a different PCB producer, if desired. For 2 PCB boards of 8 X 10 inches, PCB123 will create them for $81.00 [61]. This includes free ground shipping in the US, and is only including a 2-layer board with no soldermask or silkscreen. These layers are considered rather unnecessary for prototype boards, which are what the group is looking for. The minimum trace width is .007 inches, and the minimum space width is not available online. This could be important to find out if this manufacturer were chosen, as some parts (such as the Si4704 FM Tuner) are extremely small, and need very small trace and space widths.

PCB123 also offers free software available for download to create the PCB schematics. This software is nice in that it comes with a parts library of over 100,000 parts free, as well as an over 100 page user manual, and a part placement guide, and many other features. It will definitely be considered when selecting the program to use.

Another fabrication company that stands out from the rest is ExpressPCB. Using the same criterion as with the previous board, a price estimate is important. From their website, they use a formula to determine the final price, rather than tables. The formula they use is: "$55 + ($0.65 * NumberOfBoards *

BoardAreaInSquareInches) + ($1.00 *NumberOfBoards) + Shipping" [62]. With ordering 2 boards, with no silkscreen or soldermask layers, and a shipping fee of $9.85 for 2-Day air (the only readily available shipping quote; it may be possible to get it cheaper with slower delivery), this comes out to $171. If only one board were needed, this total would be $118. This is significantly higher than PCB123's price, although ten of it may be removable in unnecessary shipping costs.

This fabrication company also offers some free software to design the PCBs with. This software does not come with the vast library that PCB123's software does, but it does come with a basic schematic editor as well, ExpressSCH. This is extremely handy. Using schematic software that is more similar to pSPICE is enticing, as the group has plenty of experience in using that software. The schematic, when completed, can be linked into when using the PCB software, ExpressPCB. The pins are all linked to, and if the naming is used consistently, the ExpressPCB software will show the user what pins need to be connected to what other pins. Now, the software has an automated feature that may be worth looking into that will automatically connect all the different traces, but with a board as complex as this one, it may be more fool-proof if the group decides to manually trace the lines in the program.

A third option for software to use for the PCB board is Eagle. This program is pretty top-notch, and multiple good tutorials were found for it online. A great benefit to the program is that there are huge libraries, containing most ICs, available to download. However, the program is expensive, running 747 dollars for 1 user to make a board about the size this group would need. There is a freeware version offered, but it is limited to 4 x 3.2 inch board dimensions. The final board that will be used for the alarm clock will most certainly exceed these dimensions.

11.2 Implementation

The software chosen was the ExpressSCH, along with the ExpressPCB. These were chosen for their ease of use, helpful, quick tutorial [63], the fact that it was free, and most importantly, the connection between the schematic and the PCB programs for error-checking. Each group member downloaded the free programs, so that schematics created on one machine would be able to be seen, and checked, on the other member's computers.

First, the tutorial from www.usna.edu was run through, using both the ExpressSCH and the ExpressPCB software [63]. Manipulating both pieces of software became much easier after this. Next, the master schematic of the GuSu Alarm clock was created. It was important to label the pins on this schematic so that they would match the pins on the pieces of hardware itself. This schematic can be seen in the final design summary. Most of the parts had to be manually created. It was very important that each part, including the basic miscellaneous parts such as resistors and capacitors, each had their own part

names. The part names are required for linking to the PCB editor, and the PCB editor had to know what pins on each specific part (which was known by its part name) was supposed to connect to which pins on another part. Also, for simplicity, most of the signals were not passed by physical lines; rather, they were tagged with labels, and any two lines tagged with the same label were considered to be electrically connected.

The PCB editor was used to create a final PCB schematic. This process was much more involved than the first step. Each part that would be soldered onto the board had to have its true physical dimensions known, and a figure had to be created in the program for it. Although the editor did have parts such as common DIP ICs available (e.g. DIP 20, DIP 28, etc.), it did not have parts such as the buzzer, or the multiplexor, in its library, and these had to be created from scratch. If these did not match the hardware perfectly, there would be problems when the time came to install them. A list of how each piece of hardware would interface with the board was created, and is recreated below in Table 11.2.1.

Hardware	Connection Method
Microcontroller	DIP 40
Clock	DIP 16
FM Tuner	DIP 18
Digital to Analog converter	DIP 8
Zigbee	DIP 20
Op-Amp	Dip 8
5V regulator	TO-220
3.3V regulator	TO-220
Pressure Sensor	Wires to PCB
Buttons	Wires to PCB
MP3 Decoder	Wires to PCB
Batteries	Wires to PCB
LCD	Wires to PCB
Multiplexor	Custom
Buzzer	Custom

Table 11.2.1: The main pieces of hardware in the GuSu clock, and the method that each would use to interface with the PCB.

Next, each part was placed. They were placed in a manner to reduce the crossing of lines as much as possible, and to keep signals from interfering (such as the FM tuner and the Zigbee device). Of course, with the quantity of signal lines needed, it was impossible to keep any lines from crossing. While the bottom layer of the PCB is a ground layer, it was possible to trace out lines from the ground layer as well to reduce the problem. However, even using both layers, it was impossible to cross all of the signal lines. It was decided that a few wires would have to be used to cross over lines, although the number to be used was kept to a minimum.

It was decided to make a majority of the signal traces .01” in width, as that is sufficient to pass 300mA of current through with no problems [63]. However, the power traces were chosen to be .025” in width, which can handle a current load of 1A [63]. Of course, this is overkill, but as in any design, it is better to have a system that is rated to handle more of everything than is expected.

Using net listing (the handy tool that shows what each pin should connect to, when the PCB is linked to a schematic), the parts were connected as planned. The ground plane was created, and each pin was double checked. The group reviewed the design, and agreed to it after a couple of minor changes. The final PCB design is shown in section 13.0.

12.0 Budget

Dealing with budgets and the financials of a project is an important role in the design process. Budgets are normally the first things discussed when companies talk about the development of software and hardware projects. If the budget cost is too high and the projected revenues from the developed project cannot surpass the initial budget outlay chances are companies will not go ahead with that project. The same question was asked for the GuSu prototype. Was this design cost feasible? The GuSu project team definitely thought that the overall design was cost feasible for the purpose it was intended for. The team had to purchase all components and other necessary devices for the prototype to perform. Each team member asked their various companies of employment for a sponsorship on the project but was unable to get a sponsor to pay for the prototype. The team members thought of asking the local faculty and professors for a sponsor but assumed the same outcome as the team member’s employers. One of the reasons the team thought of for not being able to obtain a sponsorship was the poor economy. Businesses and faculty members of UCF were having a hard enough time paying their own costs and paying for student’s projects had not been on their list of expenditures. Although this was a disappointment the GuSu team members were able to get student discounts on some of the components purchased. The cost for this project came directly out of the team member’s pockets so these discounts helped to curb the cost of supplies and components. Seen in table 12.1 is the planned budget, this is what the team originally thought of purchasing for the GuSu prototype. Table 12.2 has information on the development budget; these are the items the team used to complete the project but already had for free. Lastly is the actual budget in table 12.3 with all of the components and devices that were bought.

Components	Prototype Cost	Production Cost
uOLED-160-G1 LCD Display	$79.99 (2) = 159.98	$79.99
Atmel ATmega644-20PU	$7.87 (1)	$7.87
Sanguino Development Kit	$25.00 (1)	$25.00
XBee Modules	$23.00 (2) = $46.00	$23.00
Appliance module asst.	$20.00 (1)	$30.00
Arduino Development Kit	Free, Josh	$25.00
ATmega168	$5.00 (2) = $10.00	$5.49
Housing/Case Supplies	$25.00 (1)	$20.00
SD Card	$4.50 (1)	$3.00
SD Card Socket	$3.95 (1)	$3.00
VMusic 2 Media Module	$29.00 (2) = $58.00	$25.00
DS1307 Clock Timer	$5.06 (1)	$5.00
TDA7000 FM Tuner	$7.00 (1)	$6.00
PIRD203B Passive Infrared Sensor	$1.90 (2) = $3.80	$1.75
PIRd203S Directional Infrared Sensor	$1.90 (2) = $3.80	$1.75
Fresnel Lens	$0.35 (5) = $1.75	$0.30
PIR Sensor Module	$6.90 (1)	$6.90
Compact PIR Sensor Module	$7.40 (1)	$7.40
CS9803 Infrared Induction Control	$0.90 (3) = $2.70	$0.90
LP8072 PIR Sensor	$0.60 (3) = $1.80	$0.60
M7612 PIR Controller	$0.90 (3) = $2.70	$0.90
Pressure Sensor	$14.50 (2) = $29.00	$14.00
STA013 MP3 Decoder	$6.90 (2) = $13.80	$12.00
28 Pin SOIC Adapter	$0.80 (2) = $1.60	$0.75
LM7805 5V Regulator	$0.51 (1)	$0.50
DE-SWADJ 3.3V Variable Regulator	$15.00 (1)	$12.00
WST-1205S Buzzer	$1.81 (1)	$1.80
LM1458 Op-Amp	$0.50 (1)	$0.50
12V Wall Wart	Free, Andrew	$12.00
EAS-4P15SA Speaker	$4.32 (1)	$4.00
TS5A23159DGSR Mux	$0.81 (1)	$0.81
Logictech Speakers	$30.00 (1)	$30.00
Printed Circuit Board	$52.50 (2) = $105.00	$30.00
Miscellaneous	$50.00 (1)	$5.00
TOTAL	$655.56	$402.21

Table 12.3: Actual Budget

13.0 Final Integration Test

The purpose of this section will help clarify all of the research and implementation that went into each component. To make the reader understand more about how the GuSu was designed, to function a walkthrough of each component and how they interact with one another will be discussed.

The main component which controls all of the other modules is the microcontroller. All of the other components are directly involved with this device. The LCD display is also another key component with the GuSu design. It connects to the microcontroller and is the way the prototype interacts with the user through a menu system and buttons to allow the prototype to perform the various functions. Another electronic component that makes the design unique is the Pressure sensors. These sensors are positioned underneath the users bed. This is the component that allows the prototype to test whether the user is in bed or not and acts accordingly by turning on or off the alarm buzzer and speaker. To wake the user from sleep the GuSu design uses audio output in the form of a speaker and a buzzer. Interacting with the audio output is also the VMusic 2 media module and the VS1003 audio decoder. The USB Flash Drive is primarily used for storage of files such as music and audio files. This connects to the audio decoder which then deciphers the audio files and outputs them to the speaker. Included with the audio components is also an FM Tuner so the user has the option of listening to FM radio. One of the last major components is the addition of the wireless ZigBee module which interacts with an appliance module. This will allow the appliance module to control external devices such as coffee machines or lamps.

The external casing design was the easiest part of the design to make. This is the housing for all of the electronic components to fit neatly together. The LCD display is shown through the front of the housing and has push buttons on top of the case to control the menu system. The power and battery backup systems are also involved with this part of the design. To power the device it is plugged into a standard AC wall outlet and also has a battery backup system. The purpose of the backup system is if a power outage occurs the GuSu alarm clock will still have power to wake the user up in the morning. Inside of the housing the components are connected to a Printed Circuit Board to have control of the devices. Shown on the next page, in Figure 13.1, is a schematic of the Printed Circuit Board for the GuSu design showing all of the components the team had selected to work with one another.

The final integration test of the project was the most important test to perform to make sure the prototype functioned correctly. The final test was a culmination of all of the other tests combined. Working in a logical and sequential order the main components were first tested and then the other component modules were added on step by step. The team used the UCF labs and breadboards to experiment with all of the components. The first device that had been tested was the microcontroller since this is the heart of the prototype. The other modules

were added onto the microcontroller one by one. After one device successfully worked with the microcontroller the team wired and soldered that component and this continued until all devices were tested and then connected. After all contacts were made and worked properly, the software testing began. Software coding was the last of the tests made on the devices. The code that was implemented onto the GuSu prototype was the control factor for all of the components. These devices are connected with ease, but without software to control the design the final outcome would have been useless.

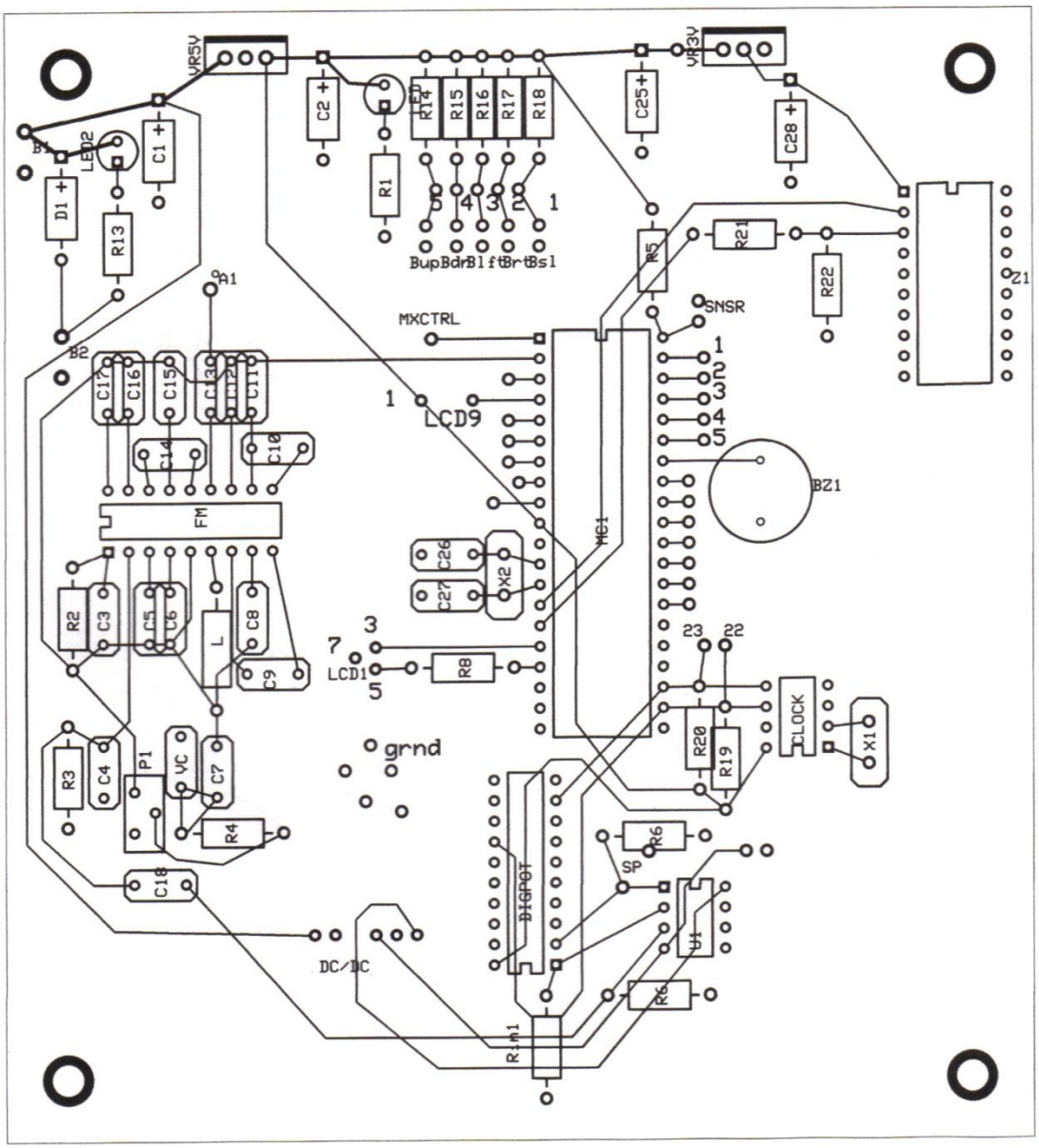


Figure 13.1: Schematic of the Printed Circuit Board with components.

14.0 Conclusion

With the American workforce being so high paced in this day and age there is a need for a new and improved alarm clock to help them with their daily lives. Many people are not satisfied with their current alarm clock setup and are looking to enhance their present design with better features and a more improved user interface. The GuSu prototype challenges this need with a better design implementation and more efficiency.

The goal of the GuSu development team was to dive into the electronic field and decide what users really wanted and needed. Most modern alarm clocks on the market today are simple and affordable for the standard user. The GuSu prototype attempts to revamp these simple alarm clocks with a more proficient design geared towards a wide genre of users. As stated in the executive summary, there are many problems with the amount of sleep each person gets every night. The GuSu prototype will ensure that everyone will get a good night's rest and will guarantee that the user is awakened whenever they need to be. The two core types of people the GuSu prototype attempts to persuade in utilizing the device are people in school and people that are in the workplace. The GuSu development team knows from personal experience how crucial it is to wake from sleep and get started on their daily activities. Not waking up in the morning seems harmless enough but it can cause major consequences down the road.

The GuSu prototype that the team has developed will help ease these troubles. The initial budget costs of the design were quite pricey but if the design was manufactured on a mass scale the overall cost to the average user could drop significantly. The components used in the GuSu prototype are standard devices that can be bought off the internet from companies that specialize in the manufacture of these specific devices. One good aspect about the GuSu prototype is its capability of adding new features and devices with relative simplicity. In the future, one big feature that could be upgraded to the average user is the Menu system. New devices will be simple to add to the microcontroller but the software would have to be implemented to control it.

Keeping in mind all of the features and usability the GuSu prototype has to offer, there are many benefits that outweigh the costs of actually building the prototype. The prototype is safe enough to be used in any location of the user's home and users of all ages will effectively be able to operate the prototype easily with simple instructions. The GuSu design also attempts to challenge the users of the prototype to come up with new ideas and features. In conclusion, the GuSu prototype will have a lasting impact on the feasibility of new alarm clock designs in the future and will help pave the way for new and improved designs.

APPENDIX A: Works Cited

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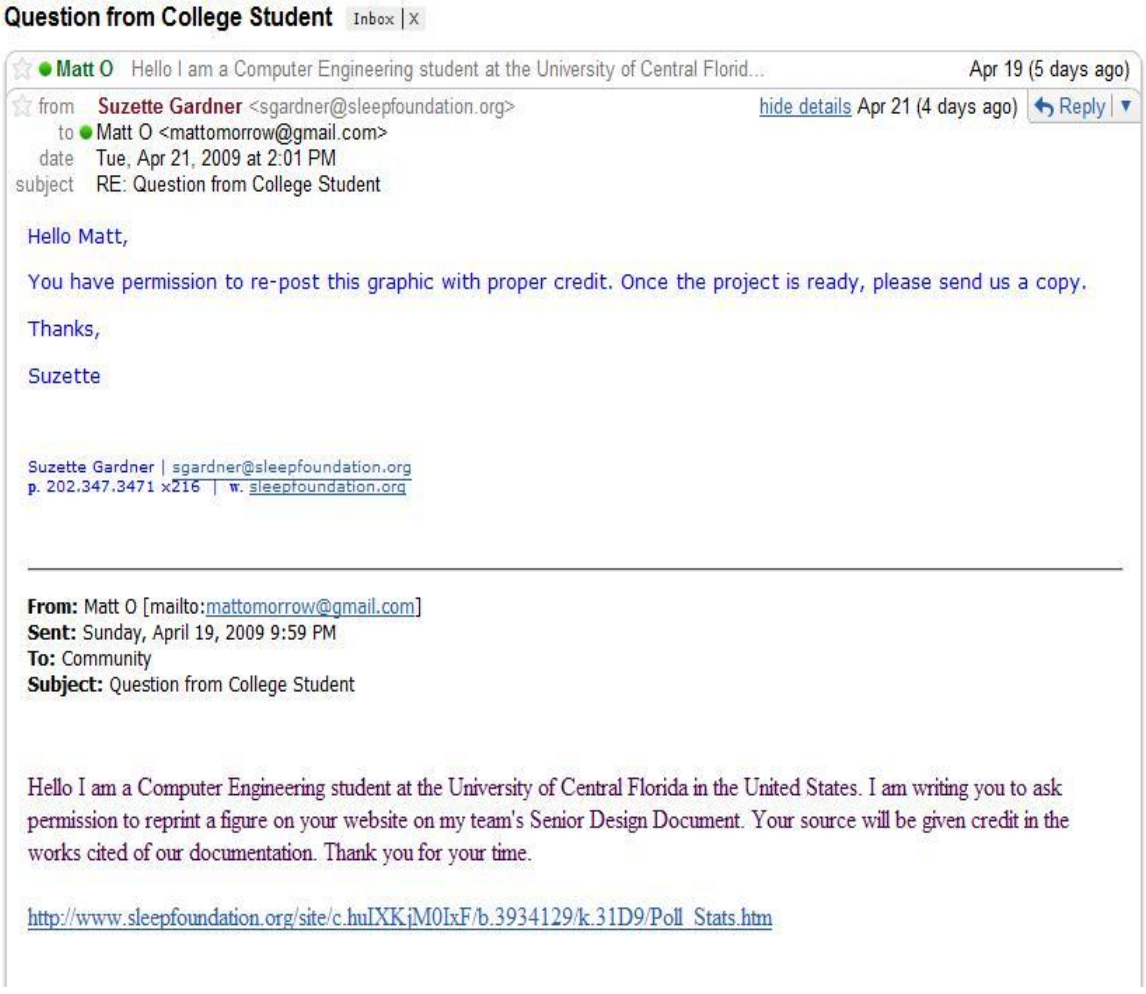
APPENDIX B: Emails

Figure 1.0.1



Question from College Student Inbox | x

Matt O Hello I am a Computer Engineering student at the University of Central Florid... Apr 19 (5 days ago)

from **Suzette Gardner** <sgardner@sleepfoundation.org> hide details Apr 21 (4 days ago) Reply

to Matt O <mattomorrow@gmail.com>
date Tue, Apr 21, 2009 at 2:01 PM
subject RE: Question from College Student

Hello Matt,

You have permission to re-post this graphic with proper credit. Once the project is ready, please send us a copy.

Thanks,

Suzette

Suzette Gardner | sgardner@sleepfoundation.org
p. 202.347.3471 x216 | w. sleepfoundation.org

From: Matt O [mailto:mattomorrow@gmail.com]
Sent: Sunday, April 19, 2009 9:59 PM
To: Community
Subject: Question from College Student

Hello I am a Computer Engineering student at the University of Central Florida in the United States. I am writing you to ask permission to reprint a figure on your website on my team's Senior Design Document. Your source will be given credit in the works cited of our documentation. Thank you for your time.

http://www.sleepfoundation.org/site/c.huIXKjM0IxF/b.3934129/k.31D9/Poll_Stats.htm

Figure 5.2.1.1

Description	LCD subpixel. It was made using POV-Ray. The POV-Ray source file is released under GPL and can be downloaded from: http://marvin.linux-box.nl/files/LCD.pov
Source	Own work
Date	12:52, 15 August 2006 (UTC)
Author	Marvin Raaijmakers, modified by ed g2s • talk
Permission (Reusing this image)	Creative Commons Attribution ShareAlike 2.5
Other versions	Image:LCD subpixel.png - textless template

Licensing [edit]

This file is licensed under the Creative Commons Attribution ShareAlike 2.5 License. In short: you are free to share and make derivative works of the file under the conditions that you appropriately attribute it, and that you distribute it only under a license identical to this one. Official license

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File history

Click on a date/time to view the file as it appeared at that time.

(latest | earliest) View (newer 50) (older 50) (20 | 50 | 100 | 250 | 500)

	Date/Time	Thumbnail	Dimensions	User	Comment
current	12:52, 15 August 2006		1,280×1,024 (250 KB)	Ed g2s	*{{Information |Description=LCD subpixel. It was made using POV-Ray. The POV-Ray source file is released under GPL and can be downloaded from: http://marvin.linux-box.nl/files/LCD.pov |Source=Own work |Date=~~~~~ |Author=Marvin Raaijmakers, modified by ~~~}*

(latest | earliest) View (newer 50) (older 50) (20 | 50 | 100 | 250 | 500)

Figure 5.2.1.2

Question from College Student

from Matt O'Morrow <mattomorrow@gmail.com> hide details 3:56 PM (48 minutes ago) Reply

to media@howstuffworks.com
date Sun, Apr 26, 2009 at 3:56 PM
subject Question from College Student
mailed-by gmail.com

Hello I am a Computer Engineering student at the University of Central Florida in the United States. I am writing you to ask permission to reprint some figures on your website on my team's Senior Design Document. Your source will be given credit in the works cited of our documentation. Thank you for your time.

http://static.howstuffworks.com/gif/oled-cell.gif

Figures 5.2.1.3, 5.2.2.1, 5.2.2.2, 5.2.3.1, 5.2.3.2

Hi Matt,

You can use the figures as long as you give proper references of the product and the company in your documentation.

Cheers

Muhammad Bilal

4D Tech Support

email: support@4dsystems.com.au

Web: http://www.4dsystems.com.au

4DGL: http://www.4dsystems.com.au/developers

Forum: http://www.websitetoolbox.com/mb/4d

From: Matt O'Morrow [mailto:matt@hudat.com]
Sent: Friday, March 13, 2009 4:12 AM
To: support@4dsystems.com.au
Subject: uOLED-160-G1 LCD Display

Matt OMorrow

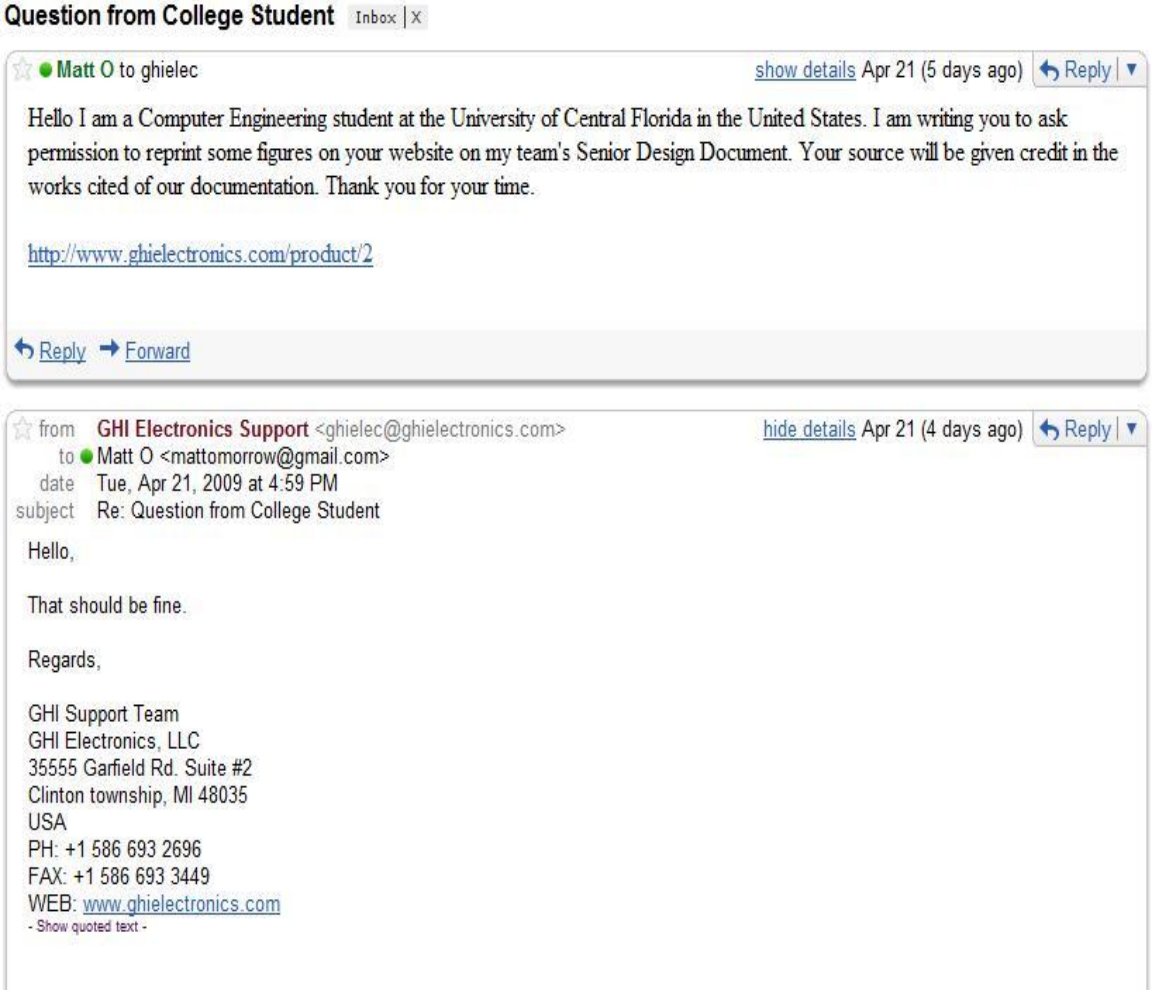
United States

matt@myacc.net

Hello, I am an engineering student at the University of Central Florida in the United States. We are working on a Senior Design project and will be using your uOLED-160-G1 LCD display. I am writing to ask for permission to use figures you have in your PDF files to add to our documentation.

uOLED-160-G1-Mech.pdf
uOLED-160-G1_Users_Manual_Rev1.0.pdf
uOLED-Connections.pdf

Figures 4.2.4.1.1, 4.2.4.1.2



Question from College Student Inbox | x

Matt O to ghielec — show details Apr 21 (5 days ago) — Reply

Hello I am a Computer Engineering student at the University of Central Florida in the United States. I am writing you to ask permission to reprint some figures on your website on my team's Senior Design Document. Your source will be given credit in the works cited of our documentation. Thank you for your time.

http://www.ghielectronics.com/product/2

Reply Forward

from **GHI Electronics Support** <ghielec@ghielectronics.com> — hide details Apr 21 (4 days ago) — Reply
to Matt O <mattomorrow@gmail.com>
date Tue, Apr 21, 2009 at 4:59 PM
subject Re: Question from College Student

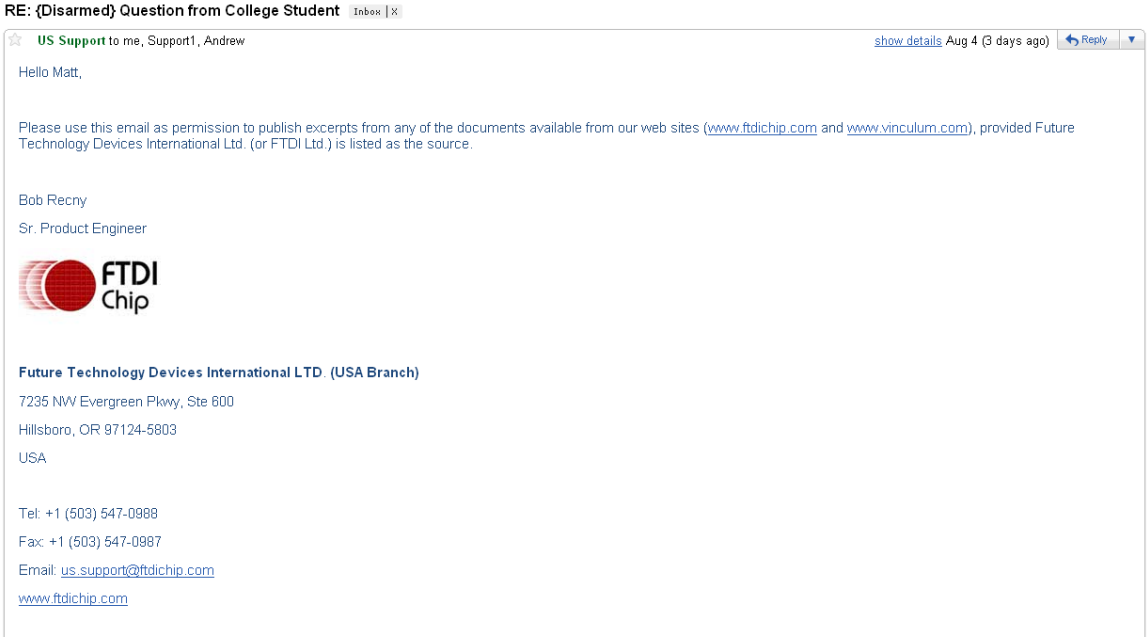
Hello,

That should be fine.

Regards,

GHI Support Team
GHI Electronics, LLC
35555 Garfield Rd. Suite #2
Clinton township, MI 48035
USA
PH: +1 586 693 2696
FAX: +1 586 693 3449
WEB: www.ghielectronics.com
- Show quoted text -

Figure 4.2.4.2.1, 4.2.4.2.2, 4.2.3.2.2



RE: {Disarmed} Question from College Student Inbox | x

US Support to me, Support1, Andrew show details Aug 4 (3 days ago) Reply

Hello Matt,

Please use this email as permission to publish excerpts from any of the documents available from our web sites (www.ftdichip.com and www.vinculum.com), provided Future Technology Devices International Ltd. (or FTDI Ltd.) is listed as the source.

Bob Recny

Sr. Product Engineer

FTDI Chip

Future Technology Devices International LTD. (USA Branch)

7235 NW Evergreen Pkwy, Ste 600

Hillsboro, OR 97124-5803

USA

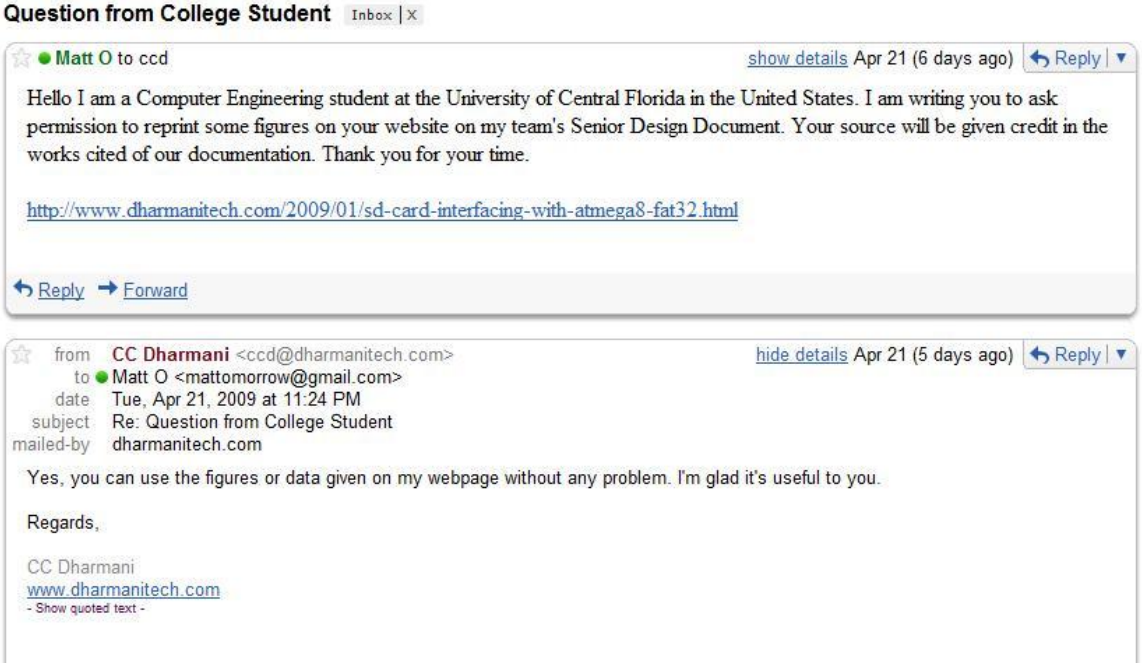
Tel: +1 (503) 547-0988

Fax: +1 (503) 547-0987

Email: us.support@ftdichip.com

www.ftdichip.com

Figure 4.2.4.2.2



Question from College Student Inbox | x

Matt O to ccd show details Apr 21 (6 days ago) Reply

Hello I am a Computer Engineering student at the University of Central Florida in the United States. I am writing you to ask permission to reprint some figures on your website on my team's Senior Design Document. Your source will be given credit in the works cited of our documentation. Thank you for your time.

http://www.dharmanitech.com/2009/01/sd-card-interfacing-with-atmega8-fat32.html

Reply Forward

from CC Dharmani <ccd@dharmanitech.com> hide details Apr 21 (5 days ago) Reply

to Matt O <mattomorrow@gmail.com>

date Tue, Apr 21, 2009 at 11:24 PM

subject Re: Question from College Student

mailed-by dharmanitech.com

Yes, you can use the figures or data given on my webpage without any problem. I'm glad it's useful to you.

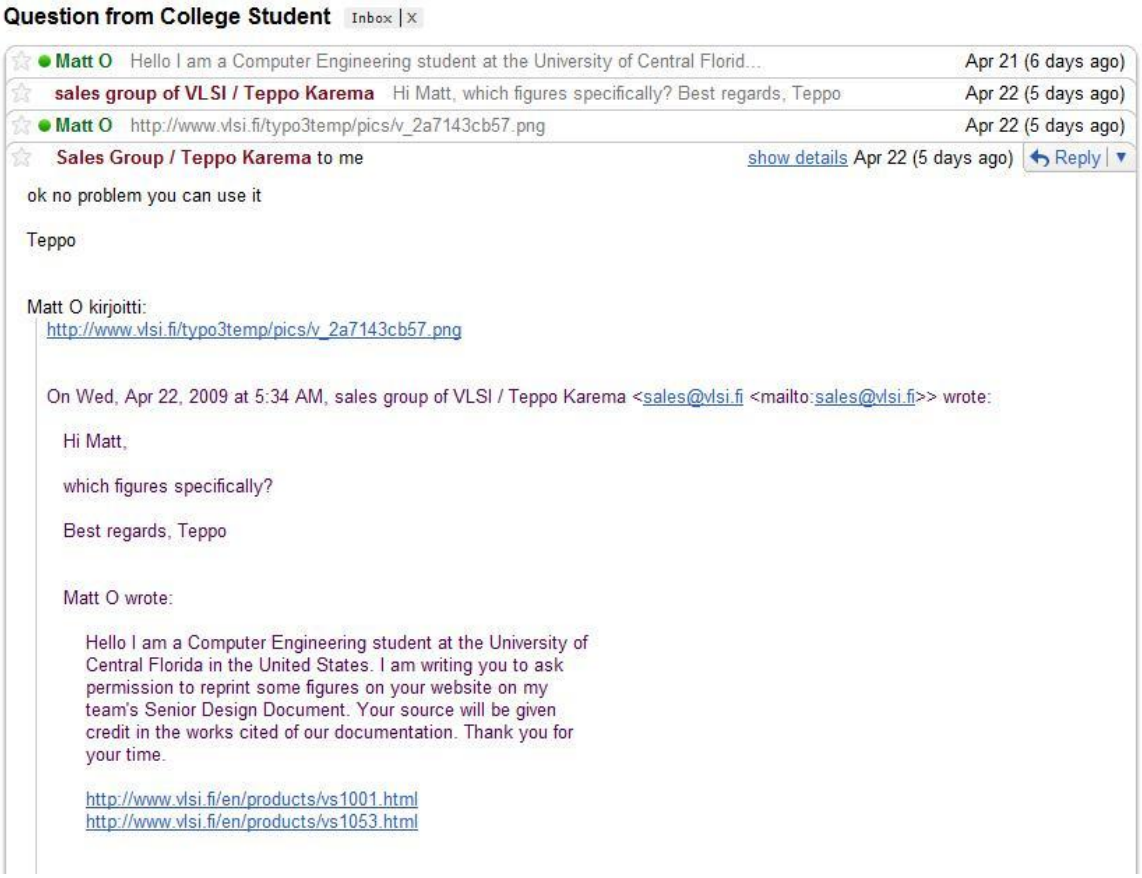
Regards,

CC Dharmani

www.dharmanitech.com

- Show quoted text -

Figure 4.2.3.1.1


Question from College Student
Inbox | x
Matt O Hello I am a Computer Engineering student at the University of Central Florid... Apr 21 (6 days ago)
sales group of VLSI / Teppo Karema Hi Matt, which figures specifically? Best regards, Teppo Apr 22 (5 days ago)
Matt O http://www.vlsi.fi/typo3temp/pics/v_2a7143cb57.png Apr 22 (5 days ago)
Sales Group / Teppo Karema to me show details Apr 22 (5 days ago) Reply
ok no problem you can use it
Teppo
Matt O kirjoitti:
http://www.vlsi.fi/typo3temp/pics/v_2a7143cb57.png
On Wed, Apr 22, 2009 at 5:34 AM, sales group of VLSI / Teppo Karema <sales@vlsi.fi <mailto:sales@vlsi.fi>> wrote:
Hi Matt,
which figures specifically?
Best regards, Teppo
Matt O wrote:
Hello I am a Computer Engineering student at the University of Central Florida in the United States. I am writing you to ask permission to reprint some figures on your website on my team's Senior Design Document. Your source will be given credit in the works cited of our documentation. Thank you for your time.
http://www.vlsi.fi/en/products/vs1001.html
http://www.vlsi.fi/en/products/vs1053.html

Figures 4.2.3.1.2

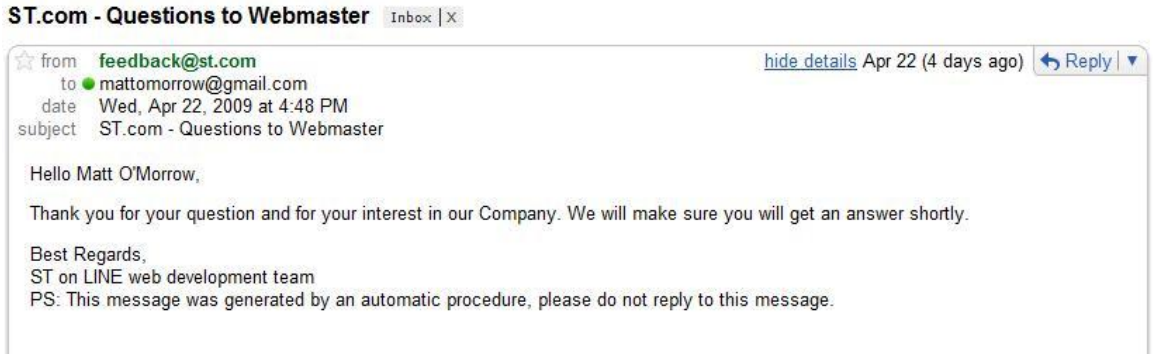
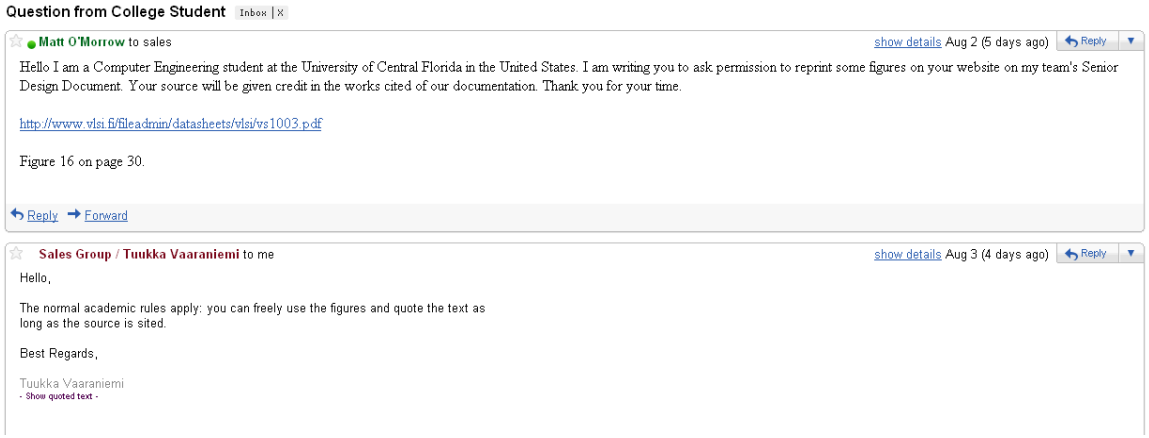

ST.com - Questions to Webmaster
Inbox | x
from feedback@st.com hide details Apr 22 (4 days ago) Reply
to mattomorrow@gmail.com
date Wed, Apr 22, 2009 at 4:48 PM
subject ST.com - Questions to Webmaster
Hello Matt O'Morrow,
Thank you for your question and for your interest in our Company. We will make sure you will get an answer shortly.
Best Regards,
ST on LINE web development team
PS: This message was generated by an automatic procedure, please do not reply to this message.

Figure 4.2.3.2.1



Question from College Student Inbox | x

Matt O'Morrow to sales — show details Aug 2 (5 days ago) Reply

Hello I am a Computer Engineering student at the University of Central Florida in the United States. I am writing you to ask permission to reprint some figures on your website on my team's Senior Design Document. Your source will be given credit in the works cited of our documentation. Thank you for your time.

http://www.vlsi.fi/fileadmin/datasheets/vlsi/vs1003.pdf

Figure 16 on page 30.

Reply Forward

Sales Group / Tuukka Vaaraniemi to me — show details Aug 3 (4 days ago) Reply

Hello,

The normal academic rules apply: you can freely use the figures and quote the text as long as the source is sited.

Best Regards,

Tuukka Vaaraniemi

- Show quoted text -

Figure 4.2.2.1.1

RE: permission to use superheterodyne block diagram

From: **Steve** (steve@microwaves101.com)
Sent: Mon 3/02/09 8:52 AM
To: 'Andrew Leger' (ajleger85@hotmail.com)

No problem!

Maybe we should add a link to your school here?

http://microwaves101.com/encyclopedia/colleges.cfm

Steve
The Unknown Editor

From: Andrew Leger [mailto:ajleger85@hotmail.com]
Sent: Sunday, March 01, 2009 5:24 PM
To: ue@microwaves101.com
Subject: permission to use superheterodyne block diagram

Hi Unknown Editor,
My name is Andrew Leger, and I am taking Senior Design at the University of Central Florida right now, working towards an undergraduate degree in Electrical Engineering. My group is doing a project that involves FM receiving, and I was hoping to have your permission to use your block diagram of the superheterodyne receiver in our group report (the diagram in question is found at http://www.microwaves101.com/encyclopedia/images/Receivers/block%20diagram.jpg). Of course, proper credit will be given to the website. Thanks for your time, and your response!

Andrew

Figure 4.2.2.1.5

RE: permission to use copyrighted picture

From: **Shannon L. Pleasant** (Shannon.Pleasant@silabs.com)
Sent: Tue 3/03/09 11:36 AM
To: ajleger85@hotmail.com

Hi Andrew, you have permissino to use the image if you could just provide us with the context it will be used in - ie the chapter or section that describes the image. Thanks! Shannon Pleasant, Director of Corporate Communications, Silicon Laboratories

---

From: Andrew Leger
To: DL.Feedback
Sent: Mon Mar 02 18:33:58 2009
Subject: permission to use copyrighted picture

Hi,
My name is Andrew Leger, and I am currently a student at UCF, working towards my undergraduate degree. We are doing a Senior Design project that incorporates an FM tuner, and we were hoping to include the image of the Si4704/05 block diagram (located at https://www.silabs.com/SiteCollectionImages/Block%20Diagrams/Si4704_05_BD.jpg) in our report. Of course, proper credit will be given. Please let me know if that would be acceptable, and thanks in advance. I realize this may not be the proper place to send it, but the 'contact us' section did not have an applicable area.

Thanks,
Andrew

Figures 4.2.4.1.3, 7.1.7.1, 9.2.1.1.2, 9.2.1.1.3, 9.2.1.1.4

From: **Marketing** (marketing@sparkfun.com)
You may not know this sender. Mark as safe | Mark as junk
Sent: Tue 3/10/09 5:08 PM
To: ajleger85@hotmail.com

Hello Andrew. Thanks for asking permission to use our images (and for the proper credit too). Of course you may use any image you like off our website for educational purposes. That goes for anyone else in your class that needs to use our images as well, so please pass along the word.

Good luck on your project!

AnnDrea Boe

—
Director of Marketing Communications
SparkFun Electronics
6175 Longbow Drive, Suite 200
Boulder, CO 80301

Begin forwarded message:

From: Andrew Leger <ajleger85@hotmail.com>
Date: March 10, 2009 3:00:03 PM MDT
To: <website@sparkfun.com>
Subject: use of copyrighted images

Hi,
My name is Andrew Leger, and I am currently a senior at UCF majoring in electrical engineering. Our senior design project will need a power supply to power a microcontroller among other things, and I was hoping I could use a few of the pictures on http://www.sparkfun.com/commerce/tutorial_info.php?tutorials_id=57 to illustrate some of the basics in our documentation report. Of course, proper credit will be given to the website. Thanks in advance,
Andrew

Figures 4.2.1.4, 4.2.2.1.4, 9.2.1.1.5

FW: Site Questions <Andrew Leger>

From: **Janette Skeim** (janette.skeim@digikey.com)
You may not know this sender. Mark as safe | Mark as junk
Sent: Thu 3/12/09 9:30 PM
To: ajleger85@hotmail.com

Hi Andrew,

You have Digi-Key Corporation's permission to use photographs from our site in your design documentation report. Thank you for taking the time to contact us and request permission to use them.

Regards,

Janette Skeim
Internet Media Production Supervisor
Digi-Key Corporation
Direct: 1-800-338-4105, ext.1351

-----Original Message-----
From: ajleger85@hotmail.com [mailto:ajleger85@hotmail.com]
Sent: Thursday, March 12, 2009 11:53 AM
To: webmaster@digikey.com
Subject: Site Questions <Andrew Leger>

Site Questions - US

First Name: Andrew
Last Name: Leger
Company: NA
Email: ajleger85@hotmail.com
Phone: (321)412-6619
Fax:

Request:
Hi, my name is Andrew Leger, and I just purchased a couple parts from your website. I am a senior at UCF and am enrolled in Senior Design, and I was wondering if I could use the images from the datasheets of these parts in out design documentation report, with proper credit given of course, or if this is something I have to email the manufacturers about.
Thanks in advance,
Andrew Leger

Figure 4.2.2.1.2

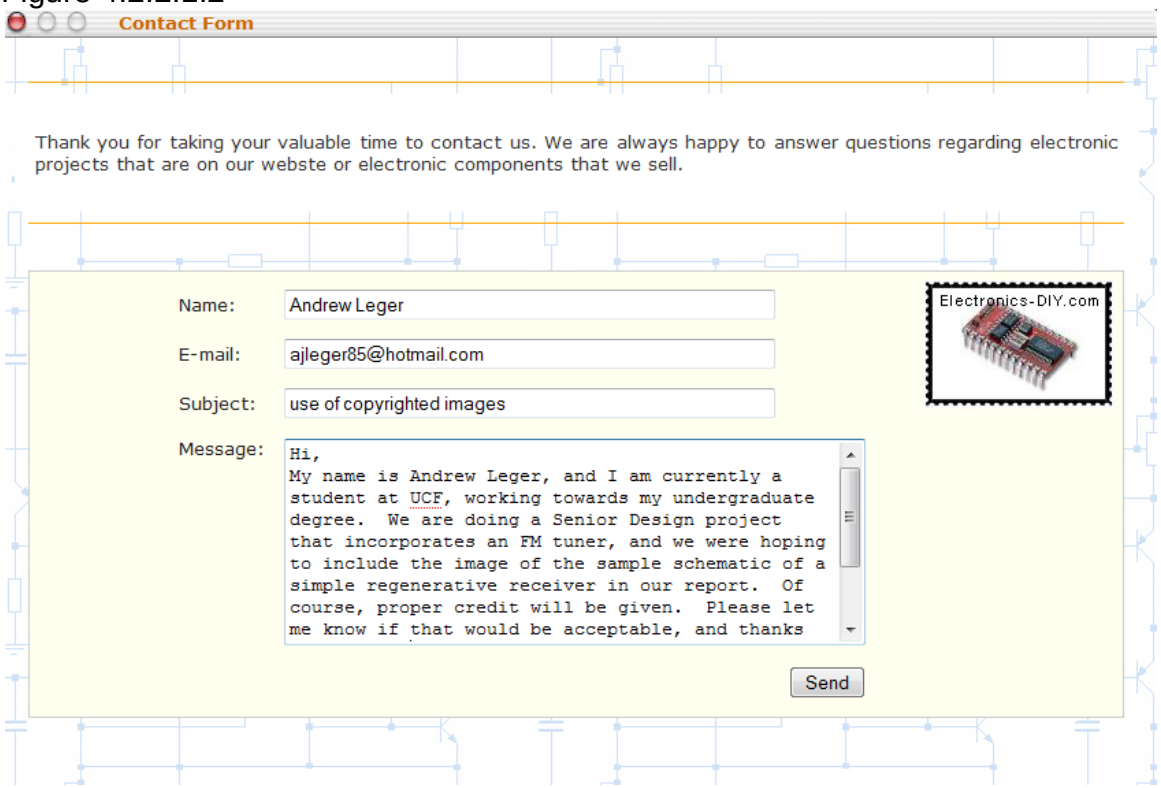
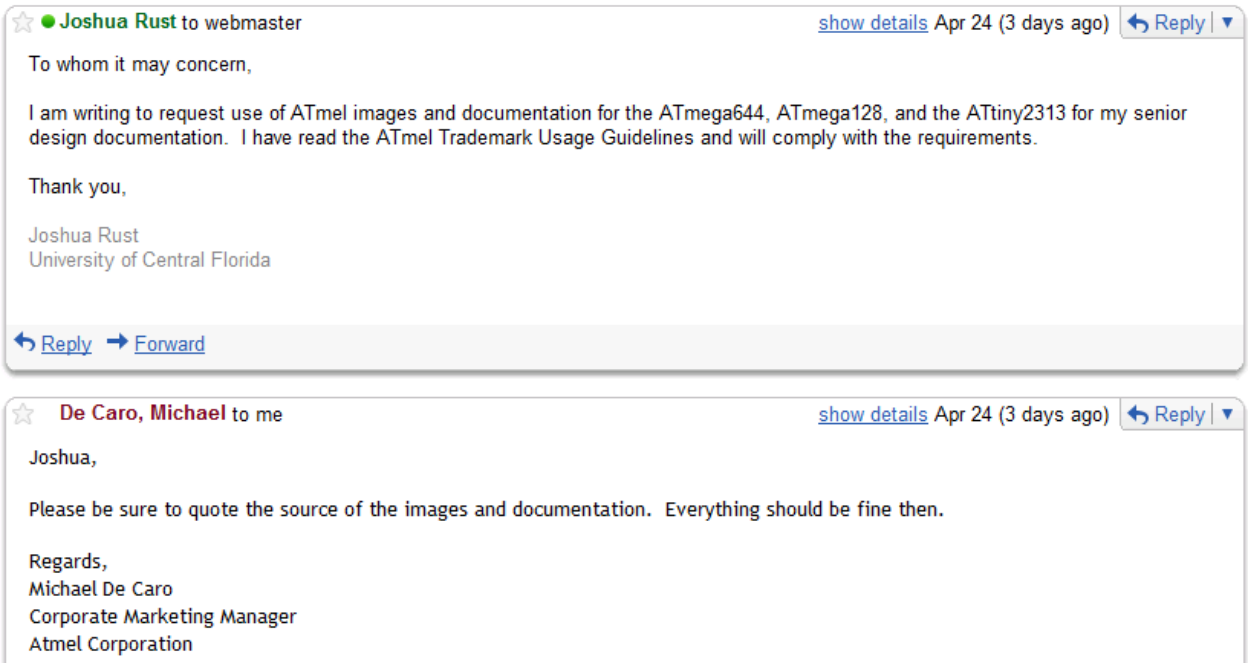

Contact Form
Thank you for taking your valuable time to contact us. We are always happy to answer questions regarding electronic projects that are on our webste or electronic components that we sell.
Name:
Andrew Leger
E-mail:
ajleger85@hotmail.com
Subject:
use of copyrighted images
Message:
Hi,
My name is Andrew Leger, and I am currently a student at UCF, working towards my undergraduate degree. We are doing a Senior Design project that incorporates an FM tuner, and we were hoping to include the image of the sample schematic of a simple regenerative receiver in our report. Of course, proper credit will be given. Please let me know if that would be acceptable, and thanks
Send
Electronics-DIY.com

Figure 3.2.2.2.1, Figure 3.3.1, Table 7.2.2.2.1



Joshua Rust to webmaster show details Apr 24 (3 days ago) Reply

To whom it may concern,

I am writing to request use of ATmel images and documentation for the ATmega644, ATmega128, and the ATtiny2313 for my senior design documentation. I have read the ATmel Trademark Usage Guidelines and will comply with the requirements.

Thank you,

Joshua Rust
University of Central Florida

Reply Forward

De Caro, Michael to me show details Apr 24 (3 days ago) Reply

Joshua,

Please be sure to quote the source of the images and documentation. Everything should be fine then.

Regards,
Michael De Caro
Corporate Marketing Manager
Atmel Corporation

Figure 8.2.2.1, Figure 8.2.2.2

|
| SPR 110591 - Staff Response - Maxim Support Center
|
| The most recent Maxim reply to your request follows below.
| If you wish to reply, you can use this fast, secure webform:
|
| https://support.maxim-ic.com/rtd/reply.mvp?id=110591&code=761F8
|
| or you can reply via e-mail. When you reply by e-mail, do not
| modify the subject line. It must contain the SPR number.
| Your response text must be at the Very Beginning of your reply.
|
|==
| Staff Comment 2009-04-24 09:15:48 PST
| By: Matthew H
|
| Joshua,
|
| Thanks for asking. Yes, you can use the material from the
| website. Please complete the attached form and return via mail or
| fax, as instructed on the form. Please attribute the quoted
| material with: "Copyright Maxim Integrated Products
| (http://www.maxim-ic.com). Used by permission."
|
| Regards,
|
| Matt Hurd
| Maxim Integrated Products
| http://www.maxim-ic.com
|
|==
| Submit Request 2009-04-24 08:50:33 PST
| By: rustytek@gmail.com
|
| To whom it may concern,
|
| I am writing to request use of ATmel images and documentation for
| the DS1305 for my senior design documentation. I will be using
| the block diagram from the datasheet and the pin layout images.
|
| Thank you,

FIGURE 6.1.1.1.1, 6.1.1.2.1

From: Navid Mokhberi <nmokhberi@futek.com>
Date: March 23, 2009 3:15:15 PM EDT
To: <koyapb@earthlink.net>
Subject: Re: website image inquiry

Phillip,

Thanks for the response and explanation of usage. You have our permission for usage. Please keep this email for your reference.

Thanks

Navid Mokhberi
Business Development Associate
navid@futek.com

FUTEK Advanced Sensor Technology, Inc.
10 Thomas, Irvine, CA 92618
V: 949.297.9660
F: 949.465.0905
Toll: 800.23.FUTEK
www.futek.com

On 3/21/09 2:42 PM, "koyapb@earthlink.net" <koyapb@earthlink.net> wrote:

> Thanks for your quick reply
>
> Me and my teammates are researching options for the design of a system
> that needs to detect if a person is in a bed, and hopefully be able to
> tell the difference between a person and a pet or luggage. So I'm

> just looking into what's out there as far as pressure/weight sensing
> goes, though we most likely will just use infrared, pressure sensing
> would have been useful for measuring exactly how much the overall
> weight including the mattress would be, allowing the system to be
> further programmed to handle multiple bed users at once, that is if
> the system knows how much each person weighs, it can tell who has left
> the bed and who hasn't.
>
> I didn't have an exact product in mind, though I was going to make use
> of the base product images for the pancake, load button, and donut
> load cells
>
> http://www.futek.com/product.aspx?stock=FSH00126&acc2=acc
> http://www.futek.com/product.aspx?stock=FSH00158&acc2=acc
> http://www.futek.com/product.aspx?stock=FSH00294&acc2=acc
>
> especially the "in use" sketch for the donut load cell to demonstrate
> how they could be positioned with a rod through the center attached to
> a board that is sized to fit under the entire mattress, allowing for
> better weight measuring.
>
> also an image demonstrating how thin the force sensors are such as
>
> http://www.futek.com/product.aspx?t=force&m=ffp350
>
> of course most of these are more industrial testing and due to

the
> complications of setup for our particular project will probably not be
> used, but our professor encourages fully researching any options.
>
> Thank you
>
> Philip Bell
> koyapb@earthlink.net
>
>
> On Mar 21, 2009, at 5:20 PM, Navid Mokhberi wrote:
>
>> Hi Philip,
>>
>> Thanks for emailing us first. We're naturally cautious how our

>> product images are used. Our general position is to allow usage as
>> long as the document/research paper doesn't position FUTEK in a
>> negative manner. Which product did you have in mind and what is the
>> synopsis of your research paper?
>>
>> Regards,
>>
>> Navid Mokhberi
>> Business Development Associate
>> navid@futek.com
>>
>> FUTEK Advanced Sensor Technology, Inc.
>> 10 Thomas, Irvine, CA 92618
>> V: 949.297.9660
>> F: 949.465.0905
>> Toll: 800.23.FUTEK
>> www.futek.com
>>
>>
>> -----Original Message-----

>> From: koyapb@earthlink.net [mailto:koyapb@earthlink.net]
>> Sent: Sat 3/21/2009 10:14 AM
>> To: Navid Mokhberi
>> Subject: website image inquiry
>>
>> Hello
>>
>> My name is Philip Bell
>> I am a Computer Engineering student at the Universitty of Central
>> Florida in Orlando Florida
>>
>> I am emailing to request permission to use some of the product images
>> for a senior design project documentation. Please let me know any
>> additional information you need from me. Thank you
>>
>> Philip Bell
>> koyapb@earthlink,net
>>
>

Figure 4.2.3.2.1

From: Paul Stoffregen <paul@pjrc.com>
Date: March 24, 2009 11:20:35 PM EDT
To: koyapb@earthlink.net
Subject: Re: [Fwd: website image inquiry]

Did you have any specific image in mind?

In general, we don't mind if you use material from the pjrc.com website for educational (non-profit) purposes.

Of course, if you require specific affirmative permission to use an image, you need to be specific about which image and how you're using it.

Robin Coon wrote:

Subject: website image inquiry
From: koyapb@earthlink.net
Date: Sat, 21 Mar 2009 13:01:05 -0400
To: robin@pjrc.com
To: robin@pjrc.com

Hello

My name is Philip Bell
I am a Computer Engineering student at the Universitty of Central Florida in Orlando, Florida

I am emailing to request permission to use some of the product images for a senior design project documentation. Please let me know any additional information you need from me. Thank you

Philip Bell
koyapb@earthlink,net

FIGURE 5.3.2.1

From: "sales" <sales@futurlec.com>
Date: April 12, 2009 6:16:43 PM EDT
To: <koyapb@ix.netcom.com>
Subject: RE: Request for use of images from the website

Dear Sir,

Thanks for your enquiry and yes, it is fine to use these images in your design documents.

Best Regards
Alan
Sales Manager
Futurlec
http://www.futurlec.com

From: koyapb@ix.netcom.com [mailto:koyapb@ix.netcom.com]
Sent: Sunday, 12 April 2009 10:44 PM
To: technical@futurlec.com
Cc: webmaster@futurlec.com; sales@futurlec.com
Subject: Request for use of images from the website

Hello, I am re-emailing a previous email that failed to deliver

My name is Philip Bell
I am a college student at University of Central Florida and wanted to request permission to use some product images in a design document, here is the email I sent previously and the message the server sent back. Let me know if there is anything else you need from me. Thank you

==========
PREVIOUS MESSAGE
==========

This message was created automatically by mail delivery software.

A message that you sent could not be delivered to one or more of its recipients. This is a permanent error. The following address(es) failed:

save to /clientmail/mail-1/f/u/futurlec.com/webmaster/

generated by webmaster@futurlec.com
mailbox is full: retry timeout exceeded

------ This is a copy of the message, including all the headers. ------

Return-path: <koyapb@earthlink.net>
Received: from pop06.mail.atl.earthlink.net ([207.69.200.40])
by smtp-mx-server-8.servers.netregistry.net protocol: esmtp (Exim 4.69 #1 (Debian))
id 1Ll4Y6-0005tq-59
for <webmaster@futurlec.com>; Sun, 22 Mar 2009 03:59:54 +1100
Received: from user-142ga72.cable.mindspring.com ([72.40.40.226] helo=[10.0.1.199])
by pop06.mail.atl.earthlink.net with esmtp (Exim 3.36 #1)
id 1Ll4YB-0005zT-00
for webmaster@futurlec.com; Sat, 21 Mar 2009 12:59:59 -0400
Message-Id: <150A126A-6B26-4EEF-8020-537DF4156B13@earthlink.net>
From: koyapb@earthlink.net
To: webmaster@futurlec.com
Content-Type: text/plain; charset=US-ASCII; format=flowed; delsp=yes
Content-Transfer-Encoding: 7bit
Mime-Version: 1.0 (Apple Message framework v930.3)
Subject: Use of website images
Date: Sat, 21 Mar 2009 12:59:59 -0400
X-Mailer: Apple Mail (2.930.3)

Hello

My name is Philip Bell
I am a Computer Engineering student at the Universitty of Central Florida in Orlando Florida

I am emailing to request permission to use some of the product images for a senior design project documentation. Please let me know any additional information you need from me. Thank you

Philip Bell
koyapb@earthlink,net

Figure 6.1.1.3.1

From: "Amy McDonough" <amcdonough@tekscan.com>
Date: March 23, 2009 4:08:12 PM EDT
To: "Philip Bell" <koyapb@earthlink.net>
Subject: FlexiForce Images

Dear Philip,

Thank you for emailing to request the use of our images. You are welcome to use any images on the website. Please let me know if you need anything else.

Best regards,
Amy

Amy McDonough *FlexiForce Sales & Marketing Assistant*
Tekscan, Inc. Phone: 617.464.4500 x245
amcdonough@tekscan.com www.tekscan.com **Order FlexiForce sensors and ELF Systems at our online shopping cart**